The Implicit Cost of Environmental Protection: Pollution Performance and Chemical Industries in the European Union

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Abstract

This thesis is about environmental competition. The underlying question is whether or not countries, or, more specifically, regulators and markets, compete among each other by the means of trading-off environmental assets such as clean air for economic performance. On the balance of the empirical results, the preliminary answer is yes – with some qualifications attached.

After a comprehensive review of the literature on approaches towards the analysis of environmental performance across various social sciences, this thesis sets out to construct a proxy indicator for environmental performance, based on the relative performance across EU countries concerning several air pollutants.

Using that indicator, this thesis classifies 15 EU member states according to their empirically observed pollution performance during the period 1990 to 1999. The classification produced four distinct clusters: poor and strong pollution performers, as well as two transition clusters.

The second part of the thesis evolves around the idea to relate air pollution performance to a number of chemical industry performance variables using panel data. The main hypothesis to be tested is whether strong pollution performance has an impact on chemical industry performance, and if so, what the sign of that relationship would be. The three performance variables are production value, employment, and value of intra-EU exports.

The results of the regression analysis show that strong pollution performance has a negative and significant impact on two of the three chemical industry performance variables, namely, on production value and intra-EU exports. On the other hand, this study does not produce evidence that strong pollution performance has an impact on the employment of the chemical industries in the EU.

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Contents

Tables

Figures

1 A Comparative Study on Environmental Competition

1.1 A popular myth –challenged

> *The old regulations, let me start off by telling you, undermined our goals for protecting the environment and growing the economy. The old regulations on the books made it difficult to either protect the economy or – protect the environment or grow the economy. Therefore, I wanted to get rid of them. I'm interested in job creation and clean air, and I believe we can do both.*

George W. Bush on his Clear Skies Initiative, speaking at the
Detroit Edison Monroe Power Plant in Monroe, Michigan, on 15 September 2003

This thesis is about environmental competition. The underlying question is whether or not countries, or, more specifically, regulators and markets, compete among each other by the means of trading-off environmental assets, such as clean air, for economic performance. There are examples in the social science literature of similar forms of competition, such as fiscal competition, or competition in the field of social security. As the above quote illustrates, the notion of environmental competition has long found its place in governmental agendas.

However, it seems that the relationship between environmental performance and economic competitiveness remains an issue with many unknowns. For one, we have considerable difficulties to define what exactly 'environmental performance' stands for. There are plenty of concepts in social science on the issue, but, as the literature review chapter will illustrate, there seems to be no integrating theory with the power to combine the approaches distinct academic disciplines.

Secondly, scholars have to face severe problems concerning environment-related data. Most of these problems fall in two broad categories, which, paradoxically, appear to stand in conflict at first sight. On the one hand, there are too little consistent and comprehensive environmental indicator data sets. If there are data series, they are often not comparable between each other. And yet, on the other hand, the amount of environment-related information that is available is incredibly large, and at times contradictory. The practical implication of these two constraints is typically that we study environmental competition selectively, based on the availability and quality of the data at hand.

Arguably, the notion of environmental competition describes a basic dilemma of our time: at some point we have to choose between, say, expanding industrial production and the preservation of the global climate. Given the enormous implications of such a choice, it seems curious how most people have accepted the alleged trade-off –quietly and without challenge.

It appears quite evident that both economic growth and environmental protection are in the interest of most people. The difficulties start when one has to rate them against each other. What is more important to us, economic welfare or environmental protection?

Of course, such a simplistic argument does not reflect the full complexity of the dilemma. Hence, there are an infinite number of variations to this theme. One could rephrase: what is more important to us, short-term economic gain or the preservation of opportunities for future generations? How about the choice between developing the means to feed starving children versus the salvation of the black-spotted owl from distinction?

The answers to this kind of questions have to come from each one of us, or alternatively, from the representatives that take such decisions in our name. Scientific analysis plays an important part in this process –by verifying the existence of the dilemma, by focusing attention on the choices we have as a society, and, if possible, by providing hints about the size of the implications we would have to expect.

My thesis aims to be a contribution to that end. In this spirit, let us get ready to crunch some numbers.

1.2 Set-up of this thesis

Research problem

This study is a comparative analysis with two main objectives. The first objective is to provide a workable measure of 'environmental performance'. To do so, we will resort to using a proxy, in the form of an air pollution indicator, which will allow us to compare the relative performance among the countries in our sample and along time. The second objective is to establish the statistical relationships between that pollution performance indicator and a number of data series about the performance of national chemical industries.

The underlying research question is whether environmental competition did take place among the countries in our sample, and what type of impact such competition had on national chemical industries. In order to address this problem, the investigation will focus on the two following questions. First, can pollution performance be shown to have a statistically significant impact on chemical industry competitiveness? And secondly, if there is such a relationship, is strong pollution performance beneficial or detrimental to chemical industry performance?

The analysis covers the 15 EU member states before the European Union's latest round of enlargement in 2004, that is, Austria, Belgium, Denmark, Finland, France, Germany Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom. The observations relate to the period between 1980 and 1999.

Aims and objectives of the research

The following points summarize the objectives of this thesis:

- Provide an example of a workable quantitative comparative analysis in the field of environmental competition. This objective includes the establishment of an extensive literature review on the current state of the art in environment-related social science, a critical justification of the methods used in this study, and the development of a proxy for environmental performance.

- Based on the findings of the comparative analysis, verify the existence and the sign of the impact of environmental competition. Obviously, the verification or rejection of the departing hypothesis is a central objective of any scientific analysis. However, in the case of this study, there is no 'preconceived' result: the issue whether or not environmental performance can be shown to have an impact on chemical industry competitiveness is very much an open question at the outset of the study. For this reason, to find the direction and strength of the statistical relationship has to be considered a crucial step in the investigation.
- A further aim of this study is to develop a deeper and more differentiated understanding of environmental competition. If the analysis showed that there is indeed a relationship between environmental performance and industrial activity, this study will attempt to differentiate the observed link. First, does environmental performance impact equally across different indicators of industrial competitiveness? Are there clusters among EU member states with regard to environmental performance? And if so, did the impact of environmental performance on industrial activity differ among those clusters?
- Contribute to the empirical literature on environmental competition in the EU. Given the huge body of literature around the economy-environment trade-off, it seems surprising how few empirical studies so far have compared EU member states. As the literature review will illustrate, there are plenty of contributions with a comparative approach among U.S. states, many case studies on individual EU member states, and some comparative analyses on a selection of EU member states.

Yet, few empirical analyses look at environmental competition among EU member states. This appears even more surprising when one considers what an interesting object of investigation the European Union currently makes: a common market with an increasingly integrated legal system – but at the same time an, in many ways, heterogeneous cluster of nation states, each attempting to guard its national interests. Interestingly, industrial and environmental policies are two policy fields in which EU member states appear to be especially reluctant to transfer powers to Brussels. All in all, it seems a rather fascinating setting for a comparative analysis.

General structure and brief overview on each chapter

There are four main parts to this thesis: a literature review that provides the context to this analysis, a detailed description on the set-up of the quantitative analysis as well as on the dependent and independent variables, the presentation of the findings of the analysis, and finally, a concluding section that discusses the findings and relates them to the literature context.

First, based on an extensive literature review, chapter 2 will provide the context to this analysis. There are two central themes which will be at the heart of the literature review. One of them revolves around the notion of environmental performance. This section describes how different fields of social science sought to understand and capture the complex idea of environmental performance. The final objective of this section is to justify why pollution performance may be considered a valid proxy for environmental performance at large. The second theme of the literature review aims to highlight theories that could help to explain the relationship between environmental performance and economic activity, and how those links can be the subject of environmental competition among countries.

Chapter 3 focuses on the presentation of the data used in the subsequent sections. The chapter starts off by describing the chemical industry, since it is the dependent variable of the regression analysis. It addresses four guiding questions: what is the chemical industry? Why is it so important? What have been the drivers of its recent restructuring? And finally, what are the links between chemical industry activity and pollution performance? The second part of chapter three introduces the independent variables. The main independent variable, air pollution performance, is presented in detail and used to construct a relative performance indicator. The remainder of the section discusses the other independent variables.

Chapter 4 is dedicated to the regression analysis. It starts by presenting the framework to the empirical study. It then reports the empirical estimations of the impact of the independent variables on chemical industry production, employment, and intra-EU exports. It also compares the predicted contribution of the explanatory variables to the actually observed figures.

Finally, chapter 5 concludes; after presenting a summary of the main findings, and discussing the contribution of the thesis to the literature, it discusses shortly future fields of research that may be pursued to follow up this study.

Summary and short discussion of the results

The research problem at the heart of this investigation is whether or not countries compete among themselves by the means of 'playing' with their environmental performance in order to foster industrial activity. The empirical results presented here appear to indicate that, on balance, the preliminary answer to that question is yes –with some qualifications attached.

In order to reach this conclusion, the first step is to construct a proxy indicator for environmental performance. As the literature review will show, there are several approaches to deal with environmental performance in social sciences. After a discussion of the advantages and disadvantages of each approach, this investigation will rely on a quantitative comparative analysis on air pollution performance patterns.

Since the frame of reference for this thesis is a closed system (the 15 EU member states), the air pollution time series reflect the relative performance of the countries within the system. The advantage of this approach is that it is comparative in nature – once the indicator is developed, one can easily work out distinct pollution performance patterns, rank countries according to their pollution performance, or classify them into performance clusters.

Using the air pollution indicator, one finding of this thesis will be the classification of EU 15 member states according to their empirically observed pollution performance during the period 1990 to 1999. The classification yields four distinct clusters. There were two "clear-cut" performance clusters with countries that were either clearly poor pollution performers or strong pollution performers. Furthermore, there are two 'transitory' pollution performance clusters. The first of those two clusters comprises countries in the process of catching-up: its constituents start from relatively poor pollution performance levels, but show convergence towards the EU average. The last cluster contains countries that fall behind in terms of pollution performance. These countries show strong initial pollution performance levels, but converge downwards towards (and in some cases, beyond) the EU average.

The second part of the thesis builds on the idea to relate the pollution performance indicator to a number of variables that capture the performance of chemical industries using panel data of the 15 countries in the sample along 20 years. The main hypothesis to be tested is whether strong pollution performance had an impact on chemical industry performance, and if so, what the sign of that relationship was. There will be three performance variables: production value, employment, and value of intra-EU exports –in order to stay within the EU as frame of reference.

The results of the regression analysis show that, with regard to two of the three chemical industry performance variables, strong pollution performance has a negative and significant impact. This is the case with regard to production value and intra-EU exports. This finding is in line with conventional economic and location theory, which states that there is a trade-off between economic performance and environmental performance. The empirical observations of this thesis lend further support to such theories. Hence, it seems that the countries in the sample actually do compete by means of environmental performance.

On the other hand, this study does not produce evidence that strong pollution performance has had an impact on the employment of the chemical industries in the EU. Hence, employment seems to respond to a different set of factors.

2 The Context: three basic concepts

This investigation departs from the notion that countries, or, to be more specific, regulators and markets, might compete with each other by adjusting their environmental performance in such a way that economic actors will be triggered to respond.

The idea that environmental performance plays a role in determining the competitive background of economies is not new, and there are a number of policy fields, such as fiscal policies (e.g., Bayindir-Upmann 1998; Biswas 2002) or social policies (Brownen 2003), in which regulative competition between countries is well documented.

The purpose of this literature review chapter is to present the current understanding in three fields of research, which are fundamental to the idea of environmental competition. The first part will provide an overview on how social scientists understand and capture the notion of environmental performance. Building on this outline, the second part will present theories on how environmental performance, and in particular pollution performance, have an impact on economic activity. Finally, given the existence of a link between environmental performance and economic activity, the third part will discuss how countries use environmental performance to acquire a comparative advantage over other countries.

2.1 Environmental performance

What is environmental performance, and how could we measure it? Judging from the wealth of different approaches in social science literature, there is more than just one way to address the issue. As this section will show, most contributions concentrate on issues like environmental policy, environmental regulation, environmental standards, or pollution performance.

There are many reasons for this variety in approaches towards environmental performance. Obviously, most scholars depart from 'their' set of theories and methods. For this reason, political scientists might rather look at environmental policies and compare them between countries, scholars of law may choose environmental regulation as their reference, and, as one should expect, environmental economists show a clear propensity towards quantifiable measures of environmental standards.

Choosing the conceptual framework that corresponds to each academic specialisation appears straightforward, convenient, and efficient. Yet, there is one crucial drawback to this multitude of approaches. The body of literature on environmental performance, as well as on the impact of environmental performance on economic performance –which one could dub the 'economy-environment trade-off'– appears deeply fragmented.

Thus, the broadness in academic approaches of the field of environmental research may be somewhat of a misperception. Although on the face of it, distinct contributions from different disciplines focus on the same issue, for instance on environmental regulation, they may actually refer to rather incompatible concepts and approaches. The subsequent literature review chapter will highlight a number of examples on this point.

However, there is one common denominator across all approaches. One central objective of environmental policies is to define the limits to the human use of the environment. The rationale behind environmental legislation is to codify and implement those policies. Finally, environmental standards may essentially be understood as the qualitative or quantitative expression of said limits concerning the human use of the environment.

Many empirical studies on environmental policies typically resort to qualitative descriptions in the form of case studies rather than using quantitative indicators. This makes the task of comparing their results rather tricky. To put it bold and simple, there appears to be no objective way to rate one environmental policy against another, let alone to score them. Environmental policies are a central and complicated area of current policies, and they affect many neighbouring policy fields such as industry, agriculture, or infrastructure. Moreover, every country has its own political culture and socio-economic background that could determine the shape and efficiency of environmental policies. With some qualification, the same appears to hold true with regard to environmental legislation analyses. In fact, the overwhelming majority of contributions in comparative environmental law are descriptive in nature.

The great advantage of qualitative studies is their flexibility in describing the observed reality; among the drawbacks of that approach can be the danger of implicit normative judgements. By contrast, quantitative measures are often focused on some specific observation; they could therefore be described as one-dimensional and inflexible. Moreover, quantitative measures can also contain implicit normative judgements, especially when they are composite indicators. However, one advantage of quantitative measures appears to be the fact that if there are implicit normative judgements involved, they should be relatively obvious to spot.

The human use of the environment generally manifests itself, inter alia, in the form of pollution. Thus, pollution is one important common denominator among the distinct scientific approaches that study the economy-environment relationship from a quantitative point of view. Looking at pollution performance provides an opportunity to compare the outcome from various environment-related theories, irrespective of their 'disciplinary' origin.

The advantages of focusing on pollution rather than on environmental policies, laws, or standards have been stressed in the literature before. For instance, Jahn (1998) argued that pollution was determined by structural, economic and political factors. As a result, he concluded that environmental policies or specific features of environmental regulation could only explain the state of the environment up to some point, but not entirely. In line with Crepaz (1995) and Jänicke et al. (1996), Jahn contended that focussing on the *outcomes* of environmental policies rather than analysing the policies themselves could be one way of overcoming this problem by providing an overview on the state of the environment as well as, indirectly, on the quality of environmental policies, regulations, and standards.

A considerable number of comparative studies, among them Lundquist (1980), Knöpfel and Weidner (1985), Henderson (1996), and Becker and Henderson (2000), take air pollution performance as one focal point of environmental policies. In fact, Crepaz (1995) and Binder (1996) note that the origins of international comparative analysis could be identified in this area of research.

Another argument in favour of focusing on pollution performance is the fact that pollution is a straightforward and, at least to some point, objective concept. This characteristic sets pollution performance indicators apart from measurements on environmental policies, environmental laws, or environmental regulation.

2.1.1 The subtle art of naming environment-related issues

One apparently trivial but on second thought fundamental problem in discussing the state of the environment is the rather confusing nomenclature around the issue in the literature. In economics and political science alone, there are literally dozens of ways to name environment-related issues.

What exactly is the environment?

There could be several reasons for this apparent conceptual vagueness. For a start, there are a number of views on how exactly one has to define the term *environment.* At the very least, the environment includes its basic physical components, or environmental media, such as water, air and soil (Birnie and Boyle 1992). Some broader definitions also include the biosphere, that is, all living things like plants or animals, as well as the interaction between the different components of the environment.

Yet, other contributions focus on some specific component of the environment, such as the medium air, or on certain environment-related processes, such as pollution. Because there is such a multitude of possible investigation foci, ranging from comprehensive to very specific, it may be little surprise that the nomenclature of environment-related issues consists of a whole range of terms.

Implicit preferences and judgements

A second cause for the wealth of terms on environment-related issues appears to be the fact that any reflection on the matter almost automatically involves personal preferences or judgements, which could manifest itself in the semantics of terming. The perception of environment-related issues and its processing in the way of academic analysis, political discourse, or every-day behaviour, seems to depend in no small part on the personal values and experiences of the processor. For this reason, there are at times several terms for the same environment-related issue. The terms may well describe the same observation or concept, but express the perception of the person who reflects on the issue.

Take as example the terms environmental *regulation*, environmental *standards*, and environmental *protection.* They could be understood to be congruent in describing the same thing – the setting of rules that define limits to the use of the environment. However, each of the terms has a distinct 'flavour', and may therefore describe a slightly distinct concept on the issue.

The wording environmental regulation appears to be the least specific among the three options, both with regard to *what kind* of rules are being taken and to *what objective* those rules have. 'Regulation' seems to be a generic term for all kinds of laws, decrees, procedures, policies and the like, and is therefore unspecific with regard to what type of environmental rule is meant. Moreover, the term does not provide any clue as to the purpose of said regulation. If the term was chosen with care, this vagueness may be exactly the intention of the person who uses the term.

The expression 'environmental standards', on the other hand, may indeed imply a statement on those two points. First, the word 'standard' appears to be a much more specific description of environmental rules. This could be a hint that the person who uses the term has a rather technical understanding of environment-related issues, as one would expect of engineers or scientists. More likely than not, 'standards' could refer to some measurable, and therefore comparable, category.

It may also be perceivable that the phrase 'standard' contained an unspoken judgement with the quality or purpose of the environmental rule in question, since it is generally associated to the notion of *higher* or *lower* standards. Most people may instinctively feel that higher standards are preferable to lower ones. That implicit value judgement becomes even more apparent if the term *environmental protection* is used to describe the setting of environment-related rules. One could argue that the phrase 'protection' seems to imply that its subject, in other words, the protected, is in need of such action.

Nuances in the wording of environment-related issues do matter not only because they may explain the vast number of sometimes congruent notions. They appear noteworthy, especially with regard to the academic literature, because the terming of environment-related issues can be an expression of concepts or value judgements that formed the basis of their analysis.

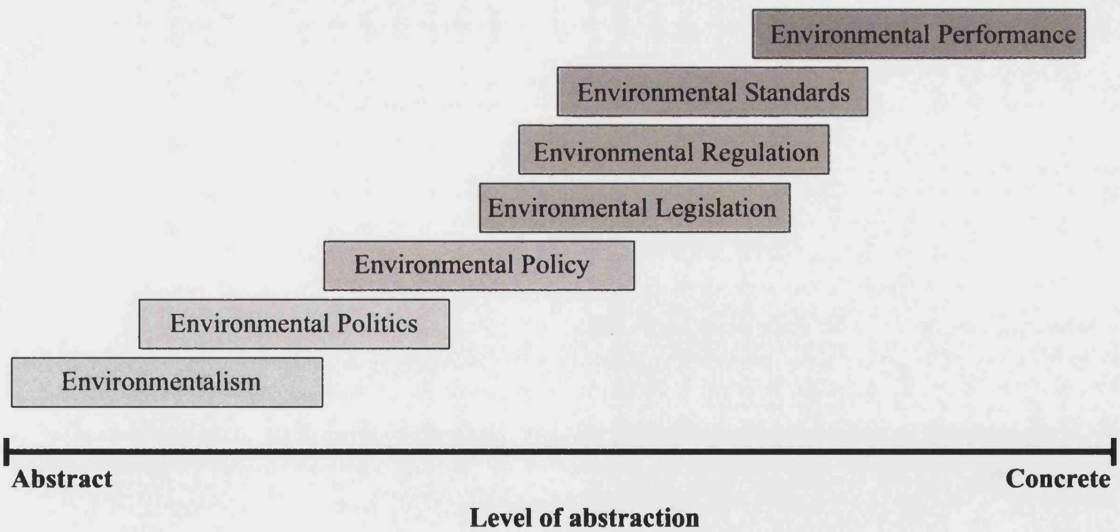
Different levels of abstraction

The study of environment-related issues in social sciences takes place on several levels of abstraction, and this may be a third reason for the multitude of environment-related terms.

Figure 1 is an attempt to illustrate this point. The concept of environmentalism is related to the public awareness about environmental issues, which in turn may depend on a variety of factors, such as the state of the environment as well as the cultural and socio-economic background of the society in question. The only direct way to measure environmentalism is through opinion polls. It may therefore be fair to state that environmentalism is a rather abstract concept in social science.

The politics of the environment are related to environmentalism, since the awareness about environmental issues among a broader public shapes the political setting. One example for this relationship may be the rise of the green party movements over the seventies and eighties across Europe, and the subsequent incorporation of environmental considerations into the political programmes of mainstream parties. No doubt, environmental politics is a rather abstract concept, but it still appears more accessible and measurable than environmentalism.

Figure 1 Spectrum of environment-related concepts in social science

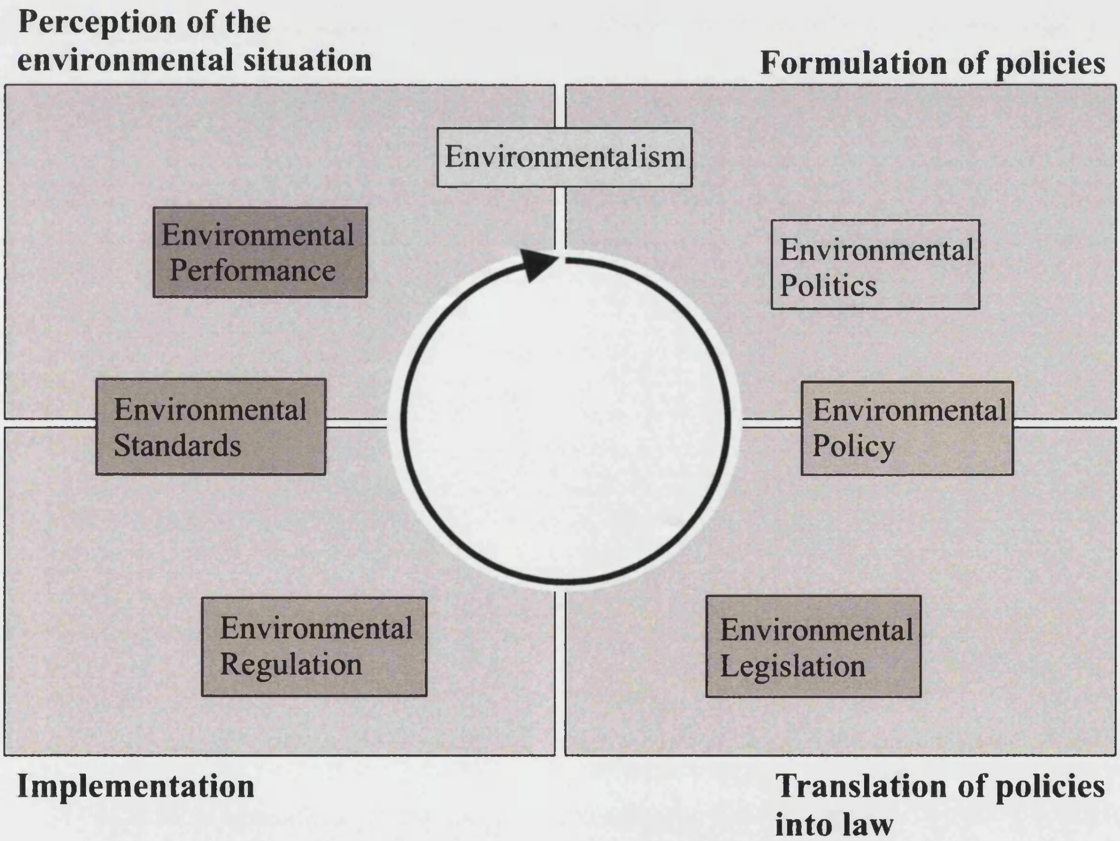


The next link in the chain is environmental policies, which may be understood as the expression of environmental politics. Again, environmental policies are a somewhat more concrete and intelligible concept than environmental politics.

The remaining environment-related concepts mentioned in the graph follow the same logic: environmental legislation is the expression of environmental policies in *legal* terms. Environmental regulation is the *institutional* expression of environmental legislation. Environmental standards are the *technical* expression of environmental regulation. And finally, environmental performance may be understood as the objectively perceivable, that is: *measurable*, expression of environmental standards.

As a last step, consider that environmentalism depends, among other factors, on the perceived state of the environment, which in turn is a function of environmental performance. One may, therefore, reach the conclusion that the spectrum of environment-related concepts laid out above is actually a loop, as depicted in figure 2.

Figure 2 An environmental policy circle



The underlying principle of this environmental policy circle (for the lack of a better term) is that societies deal with environmental issues in four stages. The first stage relates to the formulation of environmental policies: environmental issues are identified and undergo "the political process". The second stage covers the translation of environmental policies into law. The third stage represents the actual implementation of those laws. Finally, the fourth stage regards the effects of the implemented measures and their perception and closes the loop, leading back to the first stage.

2.1.2 Approaches towards the study of environmental performance in social science

As mentioned before, literature contributions related to environmental performance originate from a range of academic disciplines, most notably from political scientists, scholars of jurisprudence, economists, and geographers. Given the enormous number of theories and approaches, and especially considering the at times confusing ambiguity of the terms they use, the environmental policy circle can be an instrument to put the pieces of literature contributions into their proper context.

Each academic discipline has developed a distinct 'toolkit' of methods to capture environmental performance, and to put it into relation with, for example, economic performance. Accordingly, one way to sort the literature is by grouping the contributions according to their 'background', that is by the academic discipline they stem from.

However, the following outline follows a different structure, which reflects the logic of the environmental policy circle. There are two advantages to this approach. For one, organising literature contributions by their focus on the environmental policy circle, and not by their academic provenience or by the terms they use to describe the environment-related issue they refer to, may help the reader to keep a better overview on the matter. Secondly, the study of environment-related issues is, or at least should be, an interdisciplinary field of social science. Sorting literature not by their academic background, but by the interdisciplinary contribution they make, may help to appreciate their 'added interdisciplinary value'.

2.1.2.1 The political level: Environmental policy analysis

One way to capture the environmental performance of countries can be to look at their environmental policies. Comparisons can then be drawn both over time, as well as across countries. In the first case, a typical research question could be analogous to the following: did the subject country strengthen or weaken its environmental policies? In the latter case, one would ask how does the environmental policy regime of country x compare to the environmental policies of country y?

Focus

Typically, contributions in the field of environmental policy analysis focus on the processes which lead to the development, formalisation, and implementation of environmental policies. The most commonly used means of environmental policy analysis are socio-economic studies, political-economy analyses, or political science case studies.

Studies in this research arena often highlight "the genesis" of environmental regulation; they are therefore more often than not descriptive or analytic, as well as positive, rather than predominantly normative. It appears that this descriptive research approach is one of the main distinguishing features of this field of study vis-à-vis other bodies of environment-related literature, which focus on the outcome of environmental policies as expressed in environmental legislation, environmental standards, or environmental performance (for example, Lévêque 1996; Lévêque and Collier 1997; Lévêque and Hallett 1997).

Theories on environmental policy

Approaching the analysis of environmental policies from the perspective of political economy, Ciocirlan and Yandle (2003) highlight four possible theories to explain the process and drivers of environmental regulation. First, the so-called normative theory of environmental regulation is based on an essentially economic understanding of the objective of environmental protection, that is, as an exercise of maximising social welfare subject to constraints. The overarching objective of the regulatory authority is to serve the public interest. Accordingly, politicians following this approach would choose instruments to maximise the efficiency of environmental regulation. Unswayed by special interest pleadings, publicly-interested politicians pursue long-term goals aimed at maximising social welfare. According to economic theory, politicians need to calculate the implications of their legislation carefully, and intervene up to the point where the incremental costs of environmental intervention just offset the associated incremental benefits (Becker 1985; Stavins 1998).

Unfortunately, there is rather little empirical evidence to support this normative theory. This has led social scientists to look for alternative theories and models that could explain the environmental policy making process.

Second, the *capture theory*, which is generally attributed to the economic historian Gabriel Kolko (1963), states that politicians are sincerely willing to respond to the needs of the electorate, but lack essential information on how to do so. Therefore, they may have to rely on information and guidance provided by those who have much of it to offer, that is, the industry that is to be regulated, or the special interest groups that plead to regulate it. Because of this information asymmetry, special interest groups are likely to manipulate politicians towards their own interests.

Third, the *special interest theory* takes the *capture theory* one step further to explain which one of a number of competing special interests will be successful in gaining influence. According to this theory, politicians can be thought of as brokers who auction their services to the highest bidder. Taking into account organising and other transaction costs, the theory holds that the group that can bid the most is the group that has the most to gain or to lose when politicians act (Stigler 1971; Posner 1974; Peltzman 1976; Ciocirlan and Yandle 2003).

Fourth, the so-called *Bootleggers and Baptists theory* (Yandle 1989) departs from the notion that both environmental groups, which Yandle dubs 'Baptists', and industry (the 'bootleggers'), may advocate the pursuit of the same environmental goal. However, the motivation behind their action may be very different. Yandle argues that, although bootleggers wear the clothing of a special concern towards the environment, the implicit goals behind their actions are more related to protecting their market share and competitiveness.

Literature examples

There is a host of contributions providing case studies on the political process of environmental policy making. In order to illustrate the variety of research approaches, consider this small selection of analyses focused on the European Union: The contribution of Godard (1996) looked at the process of decision making under scientific controversy and at the limits to the applicability of the precautionary principle in the political practice. Golub (1996) analysed the process of political bargaining among national governments during EU policy making. Taking environmental policy making as example, Collier (1996) pointed out how the subsidiarity principle is exploited by EU member states in order to protect their national sovereignty.

Analysing the example of Britain and Germany, Knill and Lenschow (1997) highlighted the importance of administrative traditions to the implementation of EU environmental policies. Pallemaerts (1998) analysed the development and scope of EU policies on the export of hazardous chemicals. Krämer (2002) compared the development of environmental policies in the United States and Europe. Departing from a historic overview on the different political and legislative traditions in the two regions, he described the distinct periods of environmental policy development, which have led to fundamental differences in environmental politics today.

Although the majority of environmental policy analyses appear to stem from political scientists, there are also a number of interesting interdisciplinary contributions. For example, Damania (1999) investigated the impact of political lobbying on the choice of environmental policy instrument by means of modelling the rent seeking behaviour of the involved actors. The analysis shows that rival political parties have an incentive to set the similar or equal emission standards. Moreover, emission taxes are more likely to be supported and proposed by parties that represent environmental interest groups.

Scruggs (1999) examined the relationship between national political institutions and environmental performance in seventeen OECD countries. His study concludes that neo-corporatist societies may experience much better environmental outcomes than pluralist systems.

Summary

One of the principal achievements of this field of literature lies in the description of national environmental policy traditions, and in highlighting a whole range of different special interests that can shape environmental policies. Even if the existence and the impact of those special interests could only be captured in a descriptive way, that information is important to understand the background to the economy-environment trade-off.

The most obvious advantages of analysing environmental performance through the perspective of environmental policies lie in the flexibility of the descriptive method and in the fact that no hard quantitative data is needed. However, the complexity of political analysis, in particular the existence of "black boxes", appears to limit the 'predictive power' in linking policies to environmental outcomes.

2.1.2.2 The legislative level: Environmental legislation analysis

Another way of understanding environmental performance could be through analysing the stringency, timing or comprehensiveness of environmental legislation. The research emphasis of such an approach is the material content of regulation, as well as, in second place, its genesis.

Focus

Contributions on environmental legislation typically revolve around the layout of environmental legal and monitoring systems. Theoretical concepts in the environmental legislation arena may analyse and discuss the type or allocation of competences in environmental legislation and enforcement, which may rest at local, regional, national, or supranational level. Empirical studies often investigate and compare different types of environmental regulation, such as laws, bylaws, voluntary or negotiated agreements between regulators and private parties, as well as international legal regimes.

National traditions in command-and-control regulation

One classic topic among scholars in this field is the discussion on the advantages and drawbacks of so-called 'command and control' mechanisms. In this tradition, Héritier (1995) as well as Lübbe-Wolff (2001) compared two 'traditional' European environmental law making approaches, that is, the technical or emission-oriented approach, which is sometimes dubbed the German approach, with the quality-oriented approach of Britain. The differences between these approaches are not merely of academic interest, but have very real implications both to regulators as well as for the regulated.

In practice, emission-oriented pieces of legislation could bear a higher workload for monitoring and enforcement agencies, as all emission sources should be monitored on a regular basis. Once that technical and administrative problem of monitoring is solved, emission-oriented regulation appears rather straightforward to enforce. By contrast, the quality-oriented approach to command-and-control legislation does not so much depend on individual emission measurements, but stresses the importance that polluters, such as industrial plants, meet overall environmental quality goals. One way to implement this approach may be through integrated pollution control programmes.

Adding another 'national' approach, Gouldson and Murphy (1998) highlight the Dutch approach to environmental regulation, which is essentially anticipatory and process focused. It is typically associated with a flexible and hands-on approach to implementation and with a consultative and consensual enforcement style. One characteristic policy tool under this approach is the voluntary agreement that is negotiated between regulators and regulated.

With a view to assess the potential use of such measures at supra-national level, Khalastchi and Ward (1998) discussed the practicality of voluntary agreements at EU level. They conclude that there are a number of open issues, such as transparency or equal implementation procedures across member states, which need to be resolved before this policy tool could effectively be applied at EU level.

There are many country case studies on environmental legal systems. Among many others, Nyström (2000) highlighted the distinguishing features of the Swedish system of integrated operating permits. Delams and Terlaak (2002) compared the institutional environment for negotiated environmental agreements in the United States and three European Union member states.

Self-regulation of industries

Druckrey (1998) added another perspective by highlighting the potential for industrial self-regulation schemes. Based on a case study about the "Responsible Care" initiative of the German Chemical Industry Association, Druckrey argues that self-regulation can be an effective tool to promote ethical conduct among industrial firms. However, she notes that such behaviour needs to be supported and acknowledged by the "political and social framework".

> *If customers are prepared to pay back a company's ethical "investments" through greater demand, or if these investments improve the motivation and productivity of employees, morality can also be a part of increased competitive strength.*
>
> Druckrey (1998: 980)

However, the idea that firms may 'behave ethically' appears contended by other scholars, especially in the economic literature. As a case in point, Altman (2001) stated that private economic agents could not be expected to adopt 'green' economic policy independent of regulations since there need not be any economic advantage accruing to the affected firm in becoming greener. Along the same line of argument, Mullin (2002) pointed at the often considerable scientific uncertainty under which managers have to take environment-related business decisions. Even if companies were firmly committed to business ethics, they might not be able to judge the full consequences of their actions due to incomplete or contradicting information.

Environmental enforcement and monitoring

Dion et al. (1997) investigated whether plant-level pollution monitoring varies due to local conditions. Their data reveals that plants whose emissions are most likely to impose high environmental damages are facing a higher probability of being inspected.

According to Dion et al., the probability of inspection appears to be positively linked to the visibility of the plant. Moreover, they note that the inspection probability appeared to be a decreasing function of the regional unemployment rate. They conclude that environmental regulators do not blindly enforce uniform standards given their commonly limited resources, but distribute their resources according to local conditions.

Expanding the results of Deily and Gray (1991), Dion et al. (1997) contend that regulators appeared to *monitor* larger plants for visibility of their actions, thus satisfying one subset of their electorate. At the same time, regulators appeared to avoid *enforcing* the regulation for those larger plants, by which they satisfied another subset of their electorate.

Focusing on the issue of how infringements against pollution rules are sanctioned, Ogus and Abbot (2002) argued that enforcement policies in England and Wales may best be described as 'cautious', both with regard to seeking conviction in court as well as with regard to revoking operating licences of the offending firms. They note that such a lax sanction regime is cause for concern, as potential offenders commonly assume the costs resulting from punishment to be low, given the small probability of substantial imposition. In order to correct this, they argue in favour of other enforcement regimes, like the German system of *Ordnungswidrigkeiten*, which gives environmental agencies the power of levying administrative financial charges from offenders, without extended legal procedures and onus of proof.

Allocation of legislation and enforcement competences

Another topic that is picked up with some regularity in analyses on environmental legislation revolves around the question at which level of administration the responsibility for environmental legislation and enforcement is allocated best. For example, Millimet and Slottje (2002) assessed the impact of uniform changes in environmental compliance costs in the United States. They concluded that uniform increases in federal environmental standards had little impact on the distribution of environmental hazards. Furthermore, they found that uniform legislation could actually exacerbate spatial inequalities in this respect. Based on this conclusion, Millimet and Slottje called for environmental standards that target specific high pollution locations.

Gassner and Narodoslawsky (2001) concurred with this finding. They argued that national and international environmental standards are necessarily blind to the actual ecological impact of, for example, emissions at the regional level. Because environmental characteristics, such as climate, soil conditions or vegetation vary from region to region, there is the need to establish regional environmental quality standards, which should complement national and international ones. Another reason to call for regionally adapted standards was the fact that the man-made environment, such as the agglomeration of industrial sites causing cumulative pollution, is also region-specific.

Based on a model on optimal environmental policy in a federal system with asymmetric information, Ulph (2000) argued that setting environmental policies at federal level could be efficient when each state government only knows its local environmental damages, and if they do not co-operate. However, this effect wears off, as the welfare loss from harmonising environmental policies across states rises sharply with the variance in damage costs across states. The cost of setting federal environmental rules may erode the benefit of setting policies at the federal level to counter environmental dumping.

Summary

In conclusion, one of the most important contributions of the literature on environmental legislation is the highlighting of different traditions, approaches, and philosophies in environmental law making. To this end, most analyses on environmental law making appear to base their discussion of legal issues mainly on the means of qualitative analysis and reasoning.

Some contributions from this research arena appear to be highly relevant to our analysis, especially when they touch on cultural differences with regard to legal culture and enforcement among EU member states. However, analogous to environmental policy analyses, studies in the legal field appear to have limited predictive power when it comes to actual environmental outcomes.

2.1.2.3 The technical level: Environmental regulation and standards analysis

There is a broad body of literature that analyses the implementation of environmental policies and legislation, which generally uses the means of quantitative modelling. Under this perspective, the notion of environmental performance shifts towards the question which regulative system could be considered effective, efficient, or in line with overall welfare.

Focus

Studies in this research arena are typically rooted in environmental economics; theoretical contributions focus on questions around the design and efficiency of environmental regulation and standards. Most empirical studies in this field set out to test the validity of such theories.

By contrast to most scholars of environmental law, most contributions in environmental economics depart from an *economic* understanding on what environmental standards may be. In consequence, environmental economists understand standards not only as legally binding regulation, but also include economic instruments' like taxes or marketable pollution rights (Brückner et al. 2001; Lübbe-Wolff 2001).

Capturing environmental regulation and standards

Xing and Kolstad (1996; 2002) state that capturing environmental regulation or standards is no easy task, considering the complexity of a country's environmental regulations. For this reason, empirical studies in environmental economics seldom operate with direct measurements relating to the strictness of regulations. Instead, most investigations operate with rankings, indexes or other indicators that proxy the number, stringency, or comprehensiveness of environmental standards.

One possible approach to analyse environmental regulation in a quantitative way is to use survey data. Dasgupta et al. (2001) develop a cross-country index on environmental regulation stringency, which was compiled on the basis of United Nations Conference on Environment and Development, UNCED, reports. The index considers the state of policy and performance in four environmental dimensions: air, water, land, and living resources. Proxies for the state of environmental policies included environmental awareness, the scope of environmental legislation, and environmental control mechanisms. The same index is also applied by Wilson et al. (2002). Van Beers and van den Berg (1997) base their analysis on a measure of environmental stringency, which was entirely specified by themselves (Xing and Kolstad 2002: 3). It is no big surprise that such an approach was criticised by other contributors as "*somewhat arbitrary*" (Xing and Kolstad 2002: 3).

A second strategy to obtain a picture on the stringency or quality of environmental regulation is to use proxies, or to combine a number of proxies. For instance, Bartik (1988) uses a variety of quantitative measures in order to assess the stringency of environmental regulation. All measures used in the study were based on pollution abatement and control costs.

Similarly, List and Co (1999) use four different measures regarding the stringency of U.S. environmental regulation. The first two measures covered money spent by different regulatory agencies to control air and water pollution, and money spent to control solid waste disposal. The third measure used firm-level pollution abatement expenditures concerning air and water emissions, as well as solid waste disposals. The fourth measure was an index that combined local, state and federal government pollution efforts with firm-level abatement expenditures to assign a money-value ranking for each state in the sample.

Other literature contributions propose different proxies. Levinson (1996) includes six different indexes on the environmental stringency. Two measures on the quality of environmental regulation were provided by NGOs: one by the Conservation Foundation (Duerksen 1983), and another by the Fund for Renewable Energy and the Environment. The other four indicators covered the number of environmental statutes each state had from a list of 50 common environmental laws; the number of state employees in charge of pollution monitoring; the aggregate pollution abatement cost per state; and the industrial pollution abatement cost per state.

Mani et al. (1997) assess the level of environmental regulation by two variables: the share of government spending for environment and ecology as reflected in its budget, and the total number of environmental cases brought forward by state regulatory agencies. Smarzynska and Wei (2001) capture the stringency of a country's environmental standards by looking at its participation in international environmental treaties or regimes like the convention on long-range trans-boundary pollution, the quality of its ambient air, its water and emission standards, and the observed actual reduction in various pollutants.

Finally, another proxy for environmental regulation may be the factor time, as for example in Reitenga (2000). In this study on the cross-sectional variation in market returns of chemical industry firms following a major environmental accident, there is no direct measure on environmental regulation. Instead, Reitenga takes the catastrophe at the chemical plant in Bhopal as an external shock, after which environmental regulation is assumed to have been tightened. By doing so, he can compare the performance of chemical industries before and after the event without the need to apply proxies.

The pros and cons of different types of environmental regulation

The focus of environmental economists on market-based instruments seems strong. A substantial number of studies compare the utility and efficiency of different environmental policy instruments. For example, Jung et al. (1996) evaluate the incentive effects of five environmental regulation instruments to promote the development and adaptation of advanced pollution abatement technology. They concluded that the type of policy, which provided the most incentive for heterogeneous industries, were auctioned permits, followed by emission taxes or subsidies, and marketable permits. According to their findings, the least incentive policy was to establish performance standards.

Sandmo (2002) compares the efficiency of environmental taxes and environmental quotas under conditions of imperfect information about the degree of compliance, that is, when the regulator cannot be sure whether some firms evade taxes or exceed their quota. Sandmo concludes that the properties of the two instruments were more alike than was previously assumed in the economic literature.

Alternatives to environmental regulation

Lanoie et al. (1997), Wheeler (1997), as well as Foulon et al. (2000; 2002) investigate the impact of public disclosure programmes as a means to enforce environmental regulation. Their studies show that public disclosure of environmental performance does indeed create additional and strong incentives for pollution control. Moreover, Lanoie et al. note that their empirical evidence showed that heavy polluters were more significantly affected by mandatory disclosure than minor polluters. A survey on the theoretical literature comparing the economic efficiency of non-mandatory and mandatory environmental policy instruments can be found in the paper of Khanna (2001).

Some contributors, such as Abrego and Perroni (2002) go as far as proposing to substitute environmental policy commitment by investment subsidies. Effectively, Abrego and Perroni argue that the long-run distortionary effects of subsidies on investment choices may be sufficiently large to eliminate the need for environmental policies in this context entirely.

Getting the right mixture of environmental regulation and standards

Afsah et al. (1996) criticise the focus of the conventional policy discussion on pollution control mechanisms as "*too shallow*" and "*too narrow*". It is too shallow, because it devotes inordinate attention to instrument choice while ignoring the preconditions for applying any instrument effectively; and too narrow because it continues to focus on the interaction of regulators with firms as the sole determinant of environmental performance.

Eskeland and Devarajan (1996) argue that choosing a regulation mix of market-based as well as command-and-control approaches may be the most practicable and promising approach to environmental regulation. They note that the choice of pollution monitoring or equipment evaluation should be made in the light of feasibility and cost. They also note that environmental regulation of private sources, such as cars, was much easier than of industrial pollution sources, due to their much higher heterogeneity and complexity. Keene (1999) concurs with this finding. She notes that there are particular circumstances in which neither strict environmental regulation nor market-based instruments alone are appropriate or feasible. The challenge to policy makers and regulators lies in identifying these situations and determining which pollution management tool, or which combination of tools, regulations and market-based instruments will be most effective. Keene concludes that, in any case, the success of environmental regulation relies largely on a strong institutional and regulatory foundation.

Summary

Studies on environmental regulation and standards have contributed to the analysis of environmental performance issues in at least two ways: first, environmental economists have established an entire set of quantitative methods and indicators to analyse environmental issues. Moreover, they have also highlighted a range of market-based instruments that could complement or substitute command-and-control environmental regulation.

For these reasons, many contributions from this research arena are important as 'background information' for this study. In an ideal world with complete and comparable data on environmental standards in EU member states, a quantitative analysis on environmental regulation *would* have been the method of choice to address environmental competition. However, it is precisely the issue of data comparability that poses a seemingly unsurpassable obstacle.

Economies, as well as ecosystems, are extremely complex entities which differ between each other. The notion that there was one ideal system of environmental standards seems highly questionable. Therefore, in a comparative analysis of environmental standards, it may be hard to compare one country's set of regulations to another in an objective way. Hence, we are, metaphorically speaking, back to square one –back to qualitative statements.

2.1.2.4 Pollution performance analysis

The last cluster of literature contributions in this section does not deal with environmental policies, laws, or standards, but with their actual outcome – that is with environmental performance in the stricter sense. The basic rationale behind this approach could be summarised as follows:

> *The world is too complex to predict the detailed environmental consequences of technological changes, or of policy initiative in other areas. Thus it is important to monitor the state of the environment on a continuous basis, and to develop tools for ascertaining causal relationships.*
>
> Ayres (2001: 22)

There are several reasons why one might choose to look at environmental performance rather than at regulation itself. One of them is the straightforwardness of pollution data. As mentioned above, it appears that there is no one-to-one measure of the stringency or quality of environmental regulation. Instead, one has to resort to proxies, which may be difficult to justify. For instance, Xing and Kolstad (2002: 3) argue that proxies like pollution abatement costs were "*disquietingly ambiguous and potentially imprecise*". They argue in favour of using emission data instead, as this information was a more accurate mirror to the strictness of overall environmental regulation.

Literature examples

This approach is in line with a number of empirical contributions in the environmental economics literature that use pollution data as a basis for their analyses. Among them are Lundquist (1980), Crepaz (1995), Jänicke et al. (1996; 1997), Henderson (1996), Jahn (1998), Becker and Henderson (2000), Khanna (2000), and Neumayer (2001). However, one should not ignore the fact that environmental regulation is probably not the only determinant of pollution performance. Neumayer (2003) argues that geographical factors have often been neglected by economic analysis. His analysis on CO_2 emission data across 163 countries over the period from 1960 to 1999 shows that factors like cold climates, transportation requirements, and the availability of renewable energy sources can have an impact on emission performance.

Measuring individual environmental indicators, such as water quality or air pollution, can present a technical challenge, especially if the area or timeframe of the measurement increases in scale. However, the task of putting together individual environment-related observations into a coherent overall assessment appears to be a much larger challenge.

The much discussed book "*The Skeptical Environmentalist – Measuring the Real State of the World*" by Bjørn Lomborg (2001) may serve as an indication of the workload connected to such an exercise. In an effort that one cannot but wonder at, Lomborg lists scores of statistics about the state of the environment. In over more than 500 pages, the compilation covers 'the usual suspects' like air and water pollution, waste generation, biodiversity, and climate change, but also less frequently used environmental indicators like food yields, deforestation, energy reserves, commodity prices, and cancer rates. Lomborg's book provoked a heated debate, both on the quality of the data he presents, on the methods he employs, and on his conclusion that, looking at the big picture, the environmental situation is improving instead of deteriorating.

However, there is another point to make about Lomborg's contribution that seems more relevant in this context: the vast majority of his data is quantitative, yet Lomborg does not apply it to quantitative analysis. His final assessment of the environmental situation is essentially descriptive and fragmented into the several sub-issues he deals with. Lomborg does not attempt to put the pieces of the environmental puzzle together into an overall picture.

This apparent inability to generate a comprehensive environmental quality score is reflected in virtually the entire body of literature. The vast majority of contributions aimed at assessing environmental performance focus on specific aspects of environmental quality.

One example for this is the article of Plut (2000), which compares a number of environmental trends among EU member states and accession countries. The study uses a variety of environmental indicators, such as energy consumption, number of cars, various air pollutants, defoliation of conifers, municipal waste generation, waste water treatment plant coverage, and number of organic farms. Plut does not endeavour to combine these indicators into an overall score, but rather describes and compares each indicator across his country sample.

A different approach is to construct aggregated environmental indexes from a variety of sub-indicators. The contributions of Montgomery (1999), as well as of van den Berg and van Veen-Groot (2000), are examples of how this could be put into practice. Both contributions aim to capture the state of the environment by using several categories of sub-indicators. For instance, Montgomery (1999) proposes to develop a matrix of 60 environmental indicators, which should be divided into 10 sub-categories: air pollution, climate change, loss of biodiversity, marine environment and costal zones, ozone layer depletion, resource depletion, dispersion of toxic substances, urban environmental problems, waste, as well as water pollution and water resources. As promising as such an idea may appear one should note that the data for that matrix is not yet completely available, as its compilation is a currently ongoing project of the EU's statistical office, Eurostat.

Summary

Contributions in the field of pollution performance analyses have shown that one can assess the quality of the environment and countries' individual performance in that regard over time, keeping in mind that there are certain important limitations: Due to the complexity of the matter, no study can capture a comprehensive picture of environmental performance. Hence, serious research can only process a selection of pollution performance indicators. Consequently, studies in this field will generally have to resort to proxies, which focus on some limited aspect of the environment.

Furthermore, although the body of literature in this research arena is extensive, one recurrent problem of empirical studies appears to be clear, being the lack of comparable and complete data sets.

Nevertheless, the great advantage of approaching environmental performance through pollution performance is the straightforwardness and objectivity of the method. Therefore, in spite of the limitations mentioned above, this thesis will use pollution performance data to approximate environmental performance.

2.2 *Links between environmental performance and economic activity*

Environmental performance interacts with a country's economy in a variety of direct and indirect ways. Beforehand, the environment is the basis of the natural resource endowment of a country. But below that surface, there is a host of literature contributions asserting that environmental performance is interacting with, and indeed has the power to influence, many of the most basic 'settings' of an economy, like production costs, trade patterns, industry locations or gains from trade (Jayadevappa and Chhatre 2000).

The following section, 2.2, focuses on concepts and theories from environmental economics. Its objective is to summarise the existing literature on possible economy-environment trade-offs, and more specifically on the linkages between economic competitiveness on the one hand, and pollution performance on the other hand. It will do so by distinguishing between theories that propose *direct* links between economic performance and pollution on the one hand, and theories that put forward *indirect* interactions between the two factors.

There are a great number of survey articles on the environment-economy nexus, which formed an important departing point for this overview. The contribution by Dean (1992), focuses on giving an overview on earlier literature about trade and the environment without addressing any particular research question. The Organisation for Economic Co-operation and Development, OECD, issued two survey studies. One paper published in 1993 (OECD 1993) provides an overview on environmental policies and regulations in OECD countries, and discusses the evidence about their repercussions on industrial competitiveness. The second study (OECD 1999) is an update of the 1993 survey. It focuses on the use of economic instruments for pollution control and resource management among OECD countries.

The contribution by Beghin et al. (1994) highlights the relationship between *global* environmental problems, trade liberalisation, growth and competitiveness. Jaffe et al. (1995) focus their literature review on theories and evidence around the issue of U.S. manufacturing competitiveness vis-à-vis environmental regulation. Theories and evidence regarding the problem of monitoring and enforcement of environmental policies were the emphasis of the economic literature survey by Cohen (1998). The paper of Jayadevappa and Chhatre (2000) outlines major economic theories around international trade and environmental quality. Finally, based on an overview on the related literature contributions, Löschel (2002) discusses the significance of technological change in economic models of environmental policy.

Although literature surveys are helpful in outlining the main issues in the current debate, they also show how hard it is to capture the sheer wealth of contributions in environmental economics and related disciplines. The environment-related strands of economics are still developing and getting increasingly complex; any catalogue concerning their principle research questions risks being incomplete or outdated.

Environmental issues have gained significance in various branches of economics since the 1960s. The recognition of environmental issues as subject of economics took place gradually in several waves (Jayadevappa and Chhatre 2000). During the early stages in the development of this field of studies, the industrial pollution in industrialised countries was at the centre of attention. In the late 1970s, a new wave of contributions related environmental issues with trade analysis. Triggered by a rising degree of environmental awareness in Europe and the United States, trans-boundary environmental issues and the concept of sustainability played an increasingly important role in the literature around 1980. The notion of differential environmental regulations and their importance for the competitiveness of countries or industries gained prominence since the 1990s. Lastly, the notion of technological change induced by environmental regulation gained in prominence in the second half of the 1990s.

2.2.1 The link between economic development and pollution performance

There is a substantial body of literature on growth and the environment, which discusses the causality between a country's state of development and the state of its environment. As Jayadevappa and Chhatre (2000) and Israel and Levinson (2002) point out, one could distinguish a number of different approaches in this field of research.

Jahn (1998) builds his argument on the hypothesis that the degree of pollution depends on the physical and industrial structure of a nation. According to this notion, possible determinants of pollution could include the territorial size of a country, its population density, its climate, the size of the industrial and service sectors, and the development of industrial production.

Jahn also mentions that the wealth of a nation or economic growth rates may serve as explanatory factors for pollution levels. However, he notes that there are two competing hypotheses about the impact of those factors on pollution levels, and that this may make it difficult to work out the dominating effect. On the one hand, rich nations with a high GNP or with high economic growth might have more financial resources to combat environmental problems. On the other hand, those nations might also have higher levels of consumption, which could lead to increasing pollution pressure.

The concept of the *Environmental Kuznets Curve* is one of the most prominent theories on the development-pollution relationship. It evolves around the notion of an inverse-U-shaped relationship between the wealth of a nation and the pollution intensity of its economy (Kuznets 1955). The basic assertion of this concept is that poor economies pollute very little. As the economies expand and develop, their pollution intensity grows. With a certain degree of development achieved, however, the pollution level then decreases again for a variety of possible reasons.

Pollution as a function of development

One strand of literature contributions discusses the theoretical underpinnings of such an inverse-U-shaped pollution-income path (Thompson and Strom 1996; de Bruyn and Heintz 1999). A first approach to explain this relationship is to understand it as "*the natural progression of economic development, from clean agrarian economies to dirty industrial economies to clean service economies*" (Israel and Levinson 2002: 3). Connected to this argument is the notion that richer countries would become gradually cleaner by substituting environmentally harmful products, as they would import products whose manufacture creates the most pollution.

Some scholars produce empirical evidence to support this hypothesis. For example, relating sulphur dioxide concentrations in urban areas and dissolved oxygen levels in rivers to national income, Xepapadeas and Amri (1998) conclude that the probability of having an acceptable environmental quality increases as a country moves to a higher state of economic development.

Pollution as a function of individual preferences

An alternative argument rests on the claim that the environmental Kuznets curve exists because of individual preferences. According to this theory, an inverse-U-shaped pollution-income path might merely represent a form of non-monotonic income expansion path, or so-called *Engel Curve.* According to this concept, individual preferences with regard to environmental quality may change with distinct levels of income. In other words, poor people may not have ways to trade the environment for other goods, middle-income people would trade clean environments for other goods, and rich people may in turn give preference to the environment over other goods (Israel and Levinson 2002).

Pollution as a function of institutional capacity

The last broad group of theories on the relation between growth and environmental quality relies on *institutional characteristics* of economies. Within this group, one could distinguish three different conceptual approaches. First, a number of contributions use the notion of technology constraints to explain the poor environmental performance of less developed countries. For example, John and Pecchenino (1994) as well as Stokey (1998) argue that the observed inverse-U shape would represent a *Pareto-optimal* response to technological constraints of poor countries in the sense that it would improve the condition of the observed countries without compromising the position of other countries.

According to this argument, poor countries would employ the most polluting form of production, as, from their point of view, they were endowed with an "*excess of environmental quality*" (Israel and Levinson 2002: 6). As their economies expand, these countries would become both dirtier and richer. Once a country is sufficiently wealthy, and in consequence more polluted, the marginal cost of abating pollution becomes worthwhile, and less polluting but more expensive technologies are put in place.

A second line of argument builds on the institutional characteristics of economies with *institutional constraints*. This theory asserts that there are obstacles in poor countries that prevent them from establishing the social or political institutions necessary to regulate pollution. An example of such obstacles could be political-economic barriers, as described by Gareth Porter (1999) as well as Jones and Manuelli (2001). Once a country is sufficiently wealthy, the fixed costs of implementing the said institutions become worth incurring. At that point, institutions like environmental agencies are established, and pollution begins to decline with economic growth.

The third group of institutional explanations focuses on *returns to scale*. This theory builds on the notion that as economies expand the marginal cost of abating pollution would become cheaper because of returns to scale. Based on this rationale, authors like James and Levinson (2001) assert that larger economies abate more than smaller ones.

An important factor to consider with regard to institutional capacity is *corruption*. Modelling the interaction between the government and a private firm, López and Mitra (2000) show that corruption is not likely to preclude the existence of an inverted U-shaped Kuznets curve, but that the pollution levels corresponding to corrupt behaviour are always above the socially optimal level. Further, under corruption, the turning point of the Kuznets curve takes place at income and pollution levels above those corresponding to the social optimum.

Critique from the scientific community

In spite of numerous theoretical and empirical studies on the concept, a number of contributions contend that the notion of an Environmental Kuznets Curve was eventually revealed to be deceptive (Beghin et al. 1994; Jayadevappa and Chhatre 2000). Stern et al. (1996) argue that the problems associated with the concept and the empirical implementation of the EKC are such that its usefulness was limited to the role of a descriptive statistic.

> *The ideas that growth per se is good for the environment and that developing countries are 'too poor to be green' are incorrect. Further and more sophisticated studies [...] would clearly be more valuable than further additions to the EKC literature.*
>
> Stern (2002: 217)

As further examples of economic analyses that question the validity of the EKC hypothesis, Park and Brat (1995) show that global inequality with regard to the state of the environment among nations has grown over the period 1960 to 1988, despite an international trend of rising incomes. Jayadevappa and Chhatre (2000) note that it is not clear whether every country will follow the sequence of stages implied the EKC relationship. They go on to argue that, though the concept was intuitively important, it "*offers no information about the actual chemistry of the interactions between development and environment that is crucial for policy measures*" (Jayadevappa and Chhatre 2000: 182).

Investigating the relationship between economic growth and CO_2 emissions in the European Union over the period from 1981 to 1995, Bengochea-Morancho et al. (2001) observe that there are differences in the individual emissions of states that cannot be explained by their level of income alone. The empirical findings of Hill and Magnani (2002) appear to point in the same direction.

Ansuategi and Escapa (2002) conclude from their data that the inverted U-shaped relationship between economic growth and emissions does not appear to hold with regard to greenhouse gas emissions. They provide a number of possible reasons for this observation: Greenhouse gases may create global, not local disutility. It is therefore problematic to relate them to the growth of individual economies. More important, they argue, is the fact that greenhouse gases may have intergenerational effects, as they accumulate and impact on income over very long periods of time.

Coondoo and Dinda (2002) conduct a Granger causality test to cross-country panel data on per capita income and the corresponding per-capita CO_2 emission data. Their results indicate that there are three different types of causality relationships holding for different country groups: For the developed-country groups of North America and Western Europe, the causality was found to run from emission to income. For the country groups of Central and South America, Oceania and Japan, causality from income to emissions is obtained. Finally, for the country groups of Asia and Africa, the causality appeared bi-directional.

As part of their Granger analysis, Coondoo and Dinda established regression equations, which indicated that, with regard to the country groups of North America and Western Europe, the growth rate of emissions has become stationary around a zero mean, and a shock in the growth rate of emissions tends to generate a corresponding shock in the growth rate of income. In other words, their results appear to indicate that differences in emission levels are positively linked to disparities in income levels.

In conclusion, there are a number of theoretical arguments that could support the notion of an Environmental Kuznets Curve. Empirical evidence for the existence of such a relationship, however, appears to be – at best – mixed.

2.2.2 Theories on indirect links between the economy and pollution performance

The above mentioned literature contributions have pointed out possible *direct* links between economic indicators and pollution performance. By contrast, the following theories and concepts highlight a number of indirect links. Indirect links would exist when factors that influence pollution performance also had an impact on other economic indicators.

For example, the theories and concepts presented in section 2.2.2.1 establish that environmental regulation has certain effects on the competitive position of firms. On the other hand, there is evidence that stricter environmental regulation leads to decreased pollution emissions (Xepapadeas and de Zeeuw 1999). Hence, one could argue that there is a connection between pollution levels and the competitive position of firms in so far as the change in emissions could be attributed to environmental regulation.

Along the same line of argument, the second set of indirect effects of pollution performance on economic indicators is based on the notion that environmental taxes could have an impact on the economy on the one hand, and on pollution performance on the other hand. Basic economic theory predicts that there is a link between environmental taxes and pollution performance. As one example, Larsen and Nesbakken (1997) show that CO_2 taxes have had an impact on CO_2 emissions in Norway.

2.2.2.1 Environmental regulation and innovation

There are several important theories in economics and related sciences that elaborate the possible relationship between environmental performance – or, to be exact, the related concept of environmental regulation – and the competitive position of firms. Some theories evolve around the notion that the right type of regulation might stimulate innovation or facilitate the spreading of innovation. Other theoretical concepts depart from the idea that environmental regulation could provide competitive advantages to some firms or industries while disadvantaging others.

Innovation offsets: the Porter Hypothesis

In their article "*Toward a new conception of the environment-competitiveness relations*", Porter and van der Linde (1995) lay out an approach to frame the impact of environmental regulation on competitiveness. One central argument of the article is that conventional economic theory inevitably had to conclude that there was a clash between the ecology and the economy, because they had a static view of environmental regulation. This was because conventional theories ignored the role of environmental regulation in the development and dispersion of new technology, the improvement of processes, the design of new products, and in changing customer preferences. Such a limited conception had led to the establishment of a "*static world*", where firms had already made their cost-minimising choices, and environmental regulation inevitably raised costs. It therefore decreased the competitiveness of companies on the market.

Porter argues that one way to establish a more dynamic understanding of competitiveness was to include the concept of innovation into the equation (Porter 1990; Porter 1991).

> *Competitiveness at the industry level arises from superior productivity, either in terms of lower costs than rivals or the ability to offer products with superior value that justify a premium price.*
>
> *(...)*
>
> *Competitive advantage, then, rests not on static efficiency nor on optimizing within fixed constraints, but on the capacity for innovation and improvements that shift the constraints.*
>
> *This paradigm of dynamic competitiveness raises an intriguing possibility: in this paper, we will argue that properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them. Such* "innovation offsets," *as we call them, can not only lower the net cost of meeting environmental regulations, but can even lead to absolute advantages over firms in foreign countries not subject to similar regulations.*

Porter and van der Linde (1995: 97/98)

At the centre of this dynamic approach to competitiveness rests the assertion that firms do not always make optimal choices. According to the argument of Porter and van der Linde (1995: 99), the actual process of competition among firms is characterised by changing technological opportunities coupled with highly incomplete information, organisational inertia and control problems. Taking this point into account, environmental regulation could have an important influence on the direction of innovation by a variety of paths.

First, environmental regulation may signal companies about likely resource inefficiencies and potential technological improvements. Second, regulation with a focus on information gathering may raise corporate awareness. Third, once environmental regulation is put into force it reduces the uncertainty whether investment into environment protection would be valuable in the future. Fourth, regulation may create pressure that motivates innovation and progress. Fifth, environmental regulation could ensure that one company cannot opportunistically gain position by avoiding environmental investments. Finally, if the innovation gains did not offset the cost of compliance, or were not perceived by companies to do so, environmental regulation could be used to enforce measures to improve environmental quality.

Porter and van der Linde argue that firms innovate in response to environmental regulation in two broad forms. First, companies could simply get smarter about how to deal with pollution once it occurs or how to reduce the amount of toxic or harmful material generated. This sort of innovation would merely reduce the cost of compliance with pollution control.

The second form of innovation would address environmental impacts while *simultaneously improving* the affected product or the related processes. The benefits of the resulting innovation offsets could exceed the cost of compliance, and thus increase industrial competitiveness. Porter and van der Linde divide the potential innovation offsets into product offsets and process offsets.

Accordingly, product offsets could manifest themselves in increased product quality, safety, resale value or scrap value. Inversely, product offsets could also decrease production or product disposal costs. Production offsets would occur through higher resource productivity such as higher process yields, reduced downtime, materials savings, an improved utilisation of by-products, lower energy consumption, lower handling costs, and the like.

Many economists met the notion that environmental regulations may benefit firms, over and above improvements in environmental quality, with considerable scepticism. For example, Portney (1994: 22) states "*I disagree fundamentally with the message [that] we can avoid painful choices when setting environmental goals*". Portney, and other economists like Palmer et al. (1995) or Jaffe et al. (1995), warn policy makers to beware of a *no-cost paradigm*, arguing that new regulations do have costs, which normally would not be outweighed by their benefits.

The empirical evidence on the validity of the Porter hypothesis is mixed. Using a process analysis framework to consistently account for non-separabilities in pollution and pollution abatement practices, Smith and Walsh (2000) conclude that apparent productivity gains could appear to be greater with environmental regulation than without, even when they are not. Their finding appears to cast doubt on earlier studies that found supporting evidence for the Porter hypothesis, since they may be the result of inadequacies in the methods used to decompose the influences of productivity change.

Based on the notion that managers can be myopic, that is, that they can take wrong investment decisions, Schmutzler (2001) analyses the circumstances under which environmental regulation might raise the expected profits of firms. He identified several factors pertaining to the likelihood of innovation offsets. First, the type of regulation is important. The more flexible regulations are, the more scope they leave for innovation. Second, technological factors are important, as benefits from innovations arise mainly in the long-run. Third, the market environment needs to be conductive to innovation. In other words, there needs to be some market pressure for innovation to overcome organisational inefficiencies of the firm. And finally, the firm structure appears most important, as innovation in a firm occurs when there is communication and mutual learning between different departments and the management.

Based on empirical data on Mexican industries, Dasgupta et al. (1998) challenge one of the basic premises of the Porter hypothesis, arguing that new technology did not appear to be significantly cleaner than old one. Once their model took account for other factors that might influence environmental performance, Dasgupta et al. do not find evidence that plants with newer technology performed better than old ones with regard to environmental performance. Instead, they highlight the importance of introducing environmental management systems, such as ISO 14000, regulatory enforcement, duties to inform the public about environmental performance, employee education, and plant size.

Xepapadeas and de Zeeuw (1999) tested the standard criticism that economists have about the Porter hypothesis, which is the idea that if opportunities existed to improve the competitive position through innovation, firms would not have to be triggered by an extra cost to take them. Their model confirms this criticism, but also shows that downsizing and modernisation of firms subject to environmental regulation increases the average productivity. Another positive effect of downsizing and modernisation is the marginal decrease of profits and environmental damage.

Rege (2000) introduces a slightly different rationale why environmental regulation may improve the competitiveness of domestic industries. She departs from the notion that regulators require domestic firms to produce at the environmental standards at which they claim to produce, or otherwise impose a penalty on those firms found cheating. This would improve competitiveness because firms are forced to provide credible information about the environmental qualities of their products. Because such credible information will differentiate domestic products from other products on the world market and consumers could be more willing to buy them.

Based on their empirical analysis on 53 large Spanish companies, Garcés and Galve (2001) report that command-and-control regulation often binds companies to make environmental investments that are not productive in the conventional economic sense. They note, however, that their findings do not necessarily disagree with the Porter hypothesis, as their investigation considered only the effect of command-and-control regulation in the short term.

Mohr (2002) states results which are consistent with Porter's hypothesis, by employing a general equilibrium framework with a large number of agents, external economies of scale in production, and discrete changes in technology. His model shows that endogenous technical change makes the Porter hypothesis feasible.

Finally, based on their study on the productivity growth patterns of chemical industries at U.S. state level over the period 1988-1992, Domazlicky and Weber (2004) report that environmental regulation did show a significant positive correlation with chemical industry productivity. In that respect, their findings were inconsistent with the Porter hypothesis. However, they also point out that the lack of a significant negative relationship suggests that environmental protection measures do not appear to reduce productivity growth either.

In conclusion, the academic discussion on the validity and implications of the Porter hypothesis has sparked a lively interdisciplinary exchange of opinions. While many economists dismiss the idea on the grounds of theoretical considerations, some empirical contributions have produced supporting evidence.

The timing of induced technological change

Based on the basic notion of the Porter Hypothesis, which states that environmental regulation may induce technological change, one strand of economic literature investigates the issue of how to achieve optimal timing with regard to induced change.

Apparently on the grounds of data availability, many contributions in this research arena concentrate on CO_2 emissions as example. Nordhaus (1980; 1980b) was the first to obtain analytical expressions for the optimal pollution tax trajectory. Further contributions include, among others, Ulph and Ulph (1994; 1997), Sinclair (1994), Farzin and Tahovonnen (1996), Farzin (1996), Peck and Wan (1996), as well as Goulder and Mathai (2000).

One important consideration in this arena concerns the optimal timing to introduce environmental regulation. For instance, Wigley et al. (1996) argue that the prospect of technological change justified relatively little current abatement of CO_2 emissions. For this reason, legislators could wait until scientific advances made such abatement less costly. By contrast, Ha-Doung et al. (1996) maintain that the potential for induced technological change justifies relatively more abatement in the near term, in light of the ability of current abatement activities to contribute to learning-by-doing.

When governments wait for the optimal moment to implement environmental regulations vis-à-vis their competitors, this may result in what is sometimes called "*leapfrogging*" in an international setting (Brezis et al. 1993; Brezis and Krugman 1997). The idea behind this is that nations that benefit the most from adopting a new technology are typically those nations that currently use the worst technologies.

On the firm level, Colby et al. (1995) confirm the strategic importance of timing. They argued that the right timing in responding to environmental regulation is critical to the success of enterprises, as firms have to decide which strategy they want to pursue. On the one hand, being the first out of the blocks with a new process, product, or technology may confer an advantage in the form of favourable customer perception or the chance to shape regulation. On the other hand, being first could also be expensive, with competitors quickly following along the learning curve. There was also the risk of governments failing to reward successful innovators, or even putting them at a disadvantage. For this reason, Colby et al. (1995) argue that it made sense for firms to be opportunistic by leapfrogging a competitor just after it makes a major capital commitment into new technologies.

According to the findings of Maglia and Sassoon (1999), strictly economic factors such as productivity and the cost of labour, go a long way to explaining the lack of competitiveness of chemical industries. They also assert that lagging chemical industries cannot afford additional burdens in terms of industry regulation. Hence, they seem to dismiss the notion of leapfrogging.

2.2.2.2 Environmental regulation and barriers to market entry

Conventional economic wisdom implies that the costs connected to environmental regulation, for example pollution abatement expenditures, reduce polluters' profits. However, Stigler (1971) was one of the first to argue that regulation could be sought by industry because it constituted a barrier to entry. The implication of this hypothesis is that compliance costs should in some way increase economic rents. In response to this notion, a number of subsequent studies examine Stigler's contention, among them Jordon (1972), Neumann and Nelson (1982), and Bartel and Thomas (1985).

The evidence from these contributions, which were typically event studies of a single regulation or a subset of regulations, appears inconclusive. Some studies have concluded that compliance costs resulting from technology regulation could create barriers to entry and scarcity rents, others have reached the opposite conclusion. In the case of environmental regulation, Helland and Matsuno (2003) note that even authors examining the same regulatory event have reached opposite conclusions. For instance, this was the case with regard to the contributions of Pashigian (1984; 1986) versus Evans (1986), as well as to the studies of Maloney and McCormick (1982) versus Hughes et al. (1986).

Dean et al. (2000) estimate the effect of environmental regulations on the formation of small manufacturing establishments. Their results suggest that a greater intensity of environmental regulation is associated with fewer small business formations. Since there are no apparent effects on the formation of large establishments, Dean et al. conclude that environmental regulations put small entrants at a unit cost disadvantage.

Helland and Matsuno (2003) examine the impact of compliance costs of economic profits, using data of the U.S. Environmental Protection Agency on environmental compliance costs at industry level. Their results indicate that compliance expenditures create or increase rents for larger firms in an industry by increasing the barriers to entry. Helland and Matsuno note that these results are consistent with the theoretical prediction that economic profits are created when economies of scale in pollution abatement are coupled with restrictions on output due to environmental standards.

Empirical findings on the competitiveness and environmental behaviour of the pulp and paper industry in India published by Pradhan and Barik (1999) seem to point in the same direction. Before the background of lax environmental regulation in India, Pradhan and Barik observe that the Indian pulp and paper industry shows signs of weakening competing capacity, as it is characterised by a declining technical change and diseconomies of scale. This tendency gives an upper hand to rivals in the international market. Pradhan and Barik argue that, for these reasons, the industry is facing profitability constraints, which prevent it from switching to cleaner technologies. In consequence, the industry's pollution level as well as the use of other material continues to be high. Overall, this study appears to show that the lack of appropriate environmental regulation may lower the barriers to market entry, and that this was taken advantage of by the international competitors of the Indian pulp and paper industry.

Dooley and Fryxell (1999) as well as Hitchens (1999) contribute another view to the notion that larger firms could be more capable of complying with higher environmental standards than their competitors. Based on an empirical study about the diversification of U.S. corporations and the pollution intensity of their subsidiaries, Dooley and Fryxell (1999) report that chemical plants which were owned by more broadly diversified parents pollute on average more than facilities that were owned by more focused companies. This could lead to the conclusion that not only the size of firms plays a role in determining their capacity to reduce pollution, but also their strategic focus.

It should be noted that a very similar case of establishing entry barriers could also be made at macroeconomic level. Modelling the linkages between trade and environmental policies, Copeland (2000) states that countries, which import pollution intensive goods, may have an incentive to try to link trade agreements with environmental agreements. By doing so, they could establish barriers to the entry of the other country's good into their markets. On the other hand, countries that export pollution-intensive goods have an incentive to prevent just that – by trying to obtain binding commitments to free trade prior to negotiations over global pollution.

Lastly, Innes and Bial (2002) introduce the notion of rewarding successful innovators by raising their competitors' costs. Such "*post-innovation benefits*" could take the form of the government adopting the new innovation as the benchmark standard, and to put a penalty on all competitors that do not comply with it. Innes and Bial argue that such a strategy would introduce efficient incentives for environmental R&D without directly taxing or subsidising research.

In conclusion, both theoretical as well as empirical literature seems to point out the importance of environmental regulation in the creation of market barriers. Most contributions note that established and larger enterprises would gain from environmental regulation vis-à-vis their smaller competitors or newcomers on the market.

2.2.2.3 Environmental taxes and the economy

One important strand in the economic literature investigates the interactions between environmental policies and the tax system. Surveys on this strand of literature were carried out, among others, by Goulder (1995), Oates (1995), Bovenberg and Goulder (1998), as well as Parry and Oates (1998).

The theoretical basis of environmental taxation was laid by Arthur Cecil Pigou (1920), who introduced the notion of corrective taxes. The Pigouvian theory of taxation, which emerges in a discussion on spillover effects that impose costs on non-transacting parties, stipulates that appropriately designed taxes could limit polluting behaviour while minimizing social costs. However, Pigou later stated that, although corrective taxes seemed good in theory, they would not work in practice. He argued that environmental taxes were not likely to be set according to their environmental logic, but rather for other reasons (Pigou 1938; 1960). Ciocirlan and Yandle (2003) develop this notion further and show, based on a political economy model using OECD data, that policymakers do not commonly set taxes with a specific concern for the environment but that their primary focus is to generate revenue.

One notion that often forms the basis for investigations on environmental taxes is the so-called "*double dividend*" hypothesis, which states that environmental taxes may simultaneously improve the environment *and* reduce the economic cost of the tax system. The latter effect could seem plausible if revenues from environment-related taxes were used to reduce the rates of pre-existing taxes that distort labour and capital markets (Parry and Bento 1999; Bye 2002).

Besides the obvious benefit this strategy could bring to labour market, there are some additional benefits from environmental taxes that are, in some studies, overlooked. For example, Eskeland (2000b) mentions the benefit of environmental protection to industrial producers, such as less polluted water sources for brewers, or less congested roads for trucks. Not surprisingly, policy makers have been quick in picking-up the notion of a double dividend, as it appears to solve a number of hot political issues, like unemployment, competitiveness and taxation, at the same time (for example, European Commission 1997; 2000).

There are a number of studies that have investigated the conditions under which the double dividend hypothesis could hold. They depart from the notion that the hypothesis, in its pure form, ignores an important source of interaction between environmental taxes and the pre-existing taxes. Since environmental taxes cause the costs and prices of products to rise, they tend to discourage labour supply and investment. By doing so, environmental taxes exacerbate the efficiency cost associated with tax distortions in labour and capital markets. Only if the distortions in the pre-existing tax system are high, the introduction of environmental taxes can be a leverage to improve welfare – even without considering the improvement in environmental quality (Felder and Schleininger 2000).

Analysing the effect of hazardous waste disposal taxes on employment growth in industries that generate hazardous waste in the United States, Levinson (2000) shows that such taxes did not impose large employment losses. He notes that this finding was in line with most existing literature, but disagrees with the common explanations for this lack of measurable economic consequences. Typically, contributions put this down to the fact that (1) measures of environmental stringency were poorly quantified, (2) compliance costs were modest, (3) variance in compliance costs among jurisdictions was small, and (4) cross-section data were insufficient to explore the consequences of increasingly stringent standards. Levinson refutes some of these explanations and argues that the most compelling explanation left appeared to be that pollution-intensive industries are also those that are the least geographically footloose. In this case, environmental authorities would find themselves in the favourable position of being able to tax the most pollution-intensive industries at the highest rates without worrying about capital or labour flight to competing jurisdictions (Levinson 2000: 362).

Therefore, aside from this case, the cost from this so-called tax interaction or tax shifting effect might dominate any efficiency benefits from recycling environmental tax revenues in other tax reductions. In consequence, an environmental tax reform might typically increase rather than decrease the efficiency costs of pre-existing tax distortions. Other contributions that found theoretical or empirical evidence to limit the applicability of double dividend hypothesis, include Bovenberg and de Mooij (1994), Kennedy and Laplante (1995; 2000), Bovenberg (1998), de Mooij and Bovenberg (1998), Ligthart and van der Ploeg (1999), and Eskeland (2000a).

Goodstein (2002) questions the existence of a tax interaction effect altogether. Moreover, Goodstein (2003) points out that the entire double dividend debate has so far been held within a relatively small circle of environmental economists, arguing that their finding are largely uncontested due to a lack of critical mass in the research arena.

Highlighting the possibility that environmental tax may do bad rather than good, Oates and Schwab (1988) consider the joint determination of a tax rate on capital, and the appropriate level environmental quality. In their model, a tax on capital is used to raise revenue to finance public goods and as a distortion factor. The nature of the tax competition in their model is a capital relocation externality; in other words, capital is assumed to move to untaxed regions. Based on the model, Oates and Schwab predict too few public goods and too low a level of environmental quality relative to the first-best optimum.

Using industry-level data regarding four heavily polluting industries, Morgenstern et al. (2001) show that increased environmental spending did not generally cause a significant change in employment levels. They concluded that their data did not support the notion of a jobs-versus-the-environment trade-off.

Parry et al. (2003) compare the importance of environmental taxation to policies that foster technological innovation by investigating whether welfare gains from technological innovation that reduce future abatement costs were larger or smaller than welfare gains from optimal pollution control. Modelling welfare gains from innovation under a variety of scenarios, Parry et al. argue that such gains depended on three key factors: the initially optimal level of abatement, the speed at which innovation reduces future abatement costs, and the discount rate. Their analysis shows that welfare gains from innovation are in most cases less than the 'Pigouvian' welfare gains. Only when innovation was assumed to reduce abatement costs substantially and quickly, and when the initially optimal abatement level was fairly modest, welfare gains from innovation resulted to be greater than from optimal pollution control.

In conclusion, based on the notion of 'Pigouvian' taxes, theory holds that some forms of taxation have the potential to limit pollution. There also seems to be some theoretical basis for the existence of a double dividend. Empirical studies on those issues have not produced a coherent picture on the validity of both theories.

2.3 Environmental competition

Once we have established that there may be a range of basic relationships between environmental performance and economic activity, the mental leap towards environmental competition appears relatively minor. The following section presents a range of theories that reflect the links between the environment and economy by 'translating' them into the logic of competitive advantage analysis.

2.3.1 The trade-off between pollution performance and industrial production

Economic literature highlights the trade-off between economic production and pollution performance. A first group of contributions in this field establish the theoretical foundation of this relationship. For example, Ayres and Kneese (1969) show that pollution is inherent to the production and the consumption of an economy. Their study points at a trade-off between production and consumption on the one hand, and pollution on the other hand.

Elaborating on this basic link, a number of studies assessed its implications. If higher production levels implied increased pollution, environmental regulation that succeeds to improve the pollution performance of countries should be expected to affect production values negatively.

The issue has gained considerable prominence, since the expected negative impact of pollution reduction goals laid down in the Kyoto Protocol was one reason for the U.S. administration to withdraw from the process. Isolating that effect, literature on technological change seems to show that the cost of pollution abatement could be quite significant.

Focussing on the CO_2 reduction goals laid down in the Kyoto protocol, Weynant and Hill (1999) estimate that the potential losses in terms of GDP among industrialised nations – United States, Canada, Japan, the EU, Australia and New Zealand – add up to approximately 1 percent. In other words, industrialised countries would have to 'pay' one percent of their GDP to meet the CO_2 targets stipulated in the Kyoto Protocol. A later study by Khanna (2001) estimated considerably higher GDP losses in the region of approximately 6 percent in average.

As one might expect, other studies vehemently contested those findings. Krause et al. (2002) argue that most studies on the effects of air pollution reduction schemes had omitted important cost-reducing policy options. As a result of this, the cost estimates that those studies had produced were far too pessimistic. To reason their point, Krause et al. put forward the following cost-reducing policy options: emission cap and trading programmes, productivity-enhancing market reforms, technology programmes, and tax cuts financed from permit auction revenues. The analysis of Krause et al. concludes that an integrated least-cost strategy for mitigating greenhouse gas emissions in the United States would produce an annual net output *gain* of roughly 0.4 percent of GDP by 2010 and of about 0.9 percent in 2020.

In conclusion, economic theory puts forward the notion of a positive link between production and pollution levels. The basic notion appears to be widely accepted in the literature. However, some contributions argue that while the implied trade-off between production and pollution performance may be right, calculations on the potential economic loss due to pollution reduction may fall short of covering all economic implications.

2.3.2 The impact of environmental regulation on trade

Economists have become aware about the importance of environmental issues primarily since the 1970s when many industrialised countries began introducing significant environmental control programmes (Bailey 1993). One of the main branches of economics that have dealt with environmental considerations was the trade arena.

Because disputes about the linkages between trade and the environment have intensified over the last decades, the relationship between environmental standards and trade has become an issue at the forefront of policy debate. One example of this were the profound differences among the participants of the World Trade Organization Meeting in Seattle in 1999 over the issue whether trade agreements should be linked to international environmental standard regimes. The dispute could not be resolved, and could be considered one of the reasons that led to the failure of the meeting (Wilson et al. 2002).

The basic theory

Grubel (1975) modified the Heckscher-Ohlin model, which states that each country has a comparative advantage in the good which is relatively intense in the use of the country's relatively abundant factor. The altered model reveals that if environmental costs are not reflected in the domestic production of commodities in the trading countries, it will increase the production of goods, which would normally be imported, and decrease the production of exports. In other words, by not reflecting environmental costs one would distort the market and thus impede trade.

Theories of international trade that build on the Ricardian model (cf., Blanchard 1997; Jayadevappa and Chhatre 2000) use natural resources or climate as potential determinants of labour productivity. Such models understand productivity as a function of production factors. Some models include environmental variables as production factors, like the factor proportion model, which frequently incorporated natural resource inputs under the composite heading 'land'.

One fundamental concept of environmental economics is the notion of an environmental externality. An externality exists whenever the welfare of some agent depends not only on his or her activities but also on activities under the control of some other agent for which he is not monetarily compensated (Tietenberg 2000). The concept applies to many environment-related issues. For example, some agents such as polluting industries use environmental resources, which in turn may have impact on the welfare of others.

General equilibrium analysis

Studies which use the general equilibrium framework to investigate the determination of output take a look at the equilibrium of all three markets, i.e. goods, financial and labour (Blanchard 1997). From their perspective, one important question regarding pollution control measures is whether the reduction in potential output induced by them is symmetrical between trading sectors or not. If the impact of pollution control was relatively neutral, a country's comparative advantage would remain unchanged, although the volume and the gains from trade may decline. In effect, the terms of trade remain the same while the price of goods increases (Jayadevappa and Chhatre 2000).

When the impact of pollution control is asymmetrical, the mix of tradable goods would be expected to change (Jayadevappa and Chhatre 2000). Capital intensive trade sectors should be expected to suffer from expensive environmental control measures more than labour intensive trade sectors. The models predict that the volume and gains of trade decline more in the capital intensive sectors than in labour intensive branches. Therefore, resource diversions into environmental control activities may lead to reduced output and consumption of tradable goods. Besides an overall reduction in trade, this development would imply a real cost of environmental control to society.

Walter (1974b) shows through a general equilibrium model that environmental costs could be increased by demand for environmental quality, and that they would draw resources away from exports and imports. As a result, trade declines while the production and consumption of environmentally friendlier goods would increase.

Blackhurst (1977) puts forward the notion of environmental assimilative capacity (EAC), which is defined as the demand for aesthetic and recreational services which also considers the nature's capacity to absorb waste and the physical endowment. As a result, this demand would trigger a flow of environment-related services. The demand may vary across nations, since the EAC, the natural endowment of countries, and the value accorded to the environment might differ between them (Siebert 1992). Therefore, environmental policy of one country could affect the environmental quality in another country through specialisation and trade. It should be noted, however, that some studies on the impact of EAC on the pattern of trade could not confirm this line of argument (Pething 1976).

The impact of increased trade on the environment

The existing literature provides no conclusive picture regarding the impact of trade on the environment (Bhagwati 1993; Daly 1993; French 1993; Jayadevappa and Chhatre 2000). On the one hand, proponents of a negative impact of trade on the environment argue that trade damages natural resources both with regard to stocks as well as to on-going pollution. Other scholars contend that trade could also have positive effect on the environment.

A standard assertion of trade theory holds that trade enhances economic development. Applying this notion to the environment, one may argue that through trade-derived income, environmental technologies and management systems could be disseminated. Furthermore, trade could provide incentives for more stringent environmental standards, and may have the potential to enhance environmental harmonisation among countries. For example, using a three dimensional trade model to analyse the effects of pollution reduction, Koo (1979) concludes that trade would increase real income, and that some of these gains may be in the form of cleaner environment.

Copeland and Taylor (1994) look at the linkage between national income, pollution and trade. They show that income gains from trade do affect pollution levels. Free trade, they argued, raised real income, but also changed the composition of national output and therefore alters the incidence and level of pollution. If the pattern of trade-induced specialisation was driven only by differences in pollution policy, then aggregate world pollution might rise with trade. If income levels differed between countries, free trade would increase world pollution (Copeland and Taylor 1995).

In a later study, Copeland and Taylor (1997) contend that under certain circumstances, free trade would increase pollution while reducing real income. Such an observation, they argued, would prove their trade-induced environmental degradation hypothesis.

Free trade and the environment

As Jayadevappa and Chhatre (2000) point out, a number of arguments in the literature have the potential to weaken the argument for free trade, as they appear to show that suitable tariffs might improve world resource allocation. This notion is of course a source of controversy.

Some contributions, like the study of d'Arge and Kneese (1972), contend that measures to control trade in order to protect the environment did not have significant effects on the long-term comparative advantage or efficiency of trading partners nor on the balance of payments or domestic incomes in the short term.

Others, like Anderson and Blackhurst (1992), point out that trade liberalisation may have distinct effects on the environmental quality of countries, depending on the size of the countries and the trade pattern in which pollution intensive goods are imported and exported. They show that industrial countries' environmental standards have implications for poorer countries that engage in trade. If both the production as well as the consumption of a good causes pollution, appropriate environmental policies could improve welfare and environmental quality when the small country opens for trade. On the other hand, Anderson and Blackhurst also argue that in such a situation any trade intervention to abate pollution would reduce welfare.

However, if industrial countries produce pollution intensive goods for which there are competing imported goods, unilaterally introduced environmental standards would improve the terms of trade for poorer countries. As a result, the production of pollution intensive goods would be moved from richer to poorer economies, provided that capital is internationally mobile.

Conventional trade models suggest that unilateral environmental regulation, or harmonisation of environmental regulation, may be damaging to trade performance (Ulph 1997; 1998). Ulph notes that, in a textbook trade model of a small open economy with a welfare maximising government and no other distortions, national governments would wish to pursue free trade and full internalisation of externalities, such as environmental damages. If countries were different in terms of endowments of natural resources or in terms of their preferences regarding environmental quality, harmonisation of environmental policies would be undesirable because it would prevent the operation of environmental comparative advantages.

Ulph (1998) highlights two possible reasons for governments to manipulate their environmental policies. First, governments may engage in what Ulph calls 'strategic trade'. If markets are imperfectly competitive, and governments cannot use trade instruments, then they will have incentives to alter their environmental policies to gain a strategic trade advantage. This practice could, but does not necessarily need to, result in environmental dumping. The second reason is in line with concepts of political economy, which are based on the notion that governments might not seek to maximise welfare but rather maximise a utility function which may include social welfare but also reflect the influence of special interest groups. In the context of the European Union and based on an endogenous-policy model, Bommer (1996) argues that European integration and policy harmonisation make downward competition of national environmental standards unlikely.

Interestingly, Schneider and Wellisch (1997) show that 'the opposite of ecological dumping' may occur as well. Based on a model with international capital mobility and local pollution, they argue that in some cases local welfare maximising governments may have an incentive to discriminate against polluting industries. This assertion holds when the implicit factor reward on pollution, which is the monetary gain from exploiting the competitive advantage due to ecological dumping, leaves the country because it accrues to foreign owners of mobile capital.

Harris et al. (2002) note that most empirical studies have concluded that the contribution of environmental costs to the overall production costs is still very marginal. In consequence, they argue that environmental policies have hardly any effect on comparative advantage patterns and thus on foreign trade. Ferrer-i-Carbonell et al. (2000) estimate the impact of environment-related taxes on prices for energy and transport. Their study shows that the demand for energy and transport are generally inelastic. The price elasticity was found to be significantly different from zero but smaller than 1. That means that a 1 percent increase of prices would lead to a reduction in demand of less than 1 percent. In the long run, however, the reduction appeared to be larger because economic agents have a wider range of options available for responding, such as new techniques, reorganisation, relocation or shifting to other goods or services.

The notion of environmental costs being marginal was challenged by Beers and van den Bergh (1997) who reports that stricter environmental regulation has some negative impact on bilateral trade flows between OECD countries. Jayadevappa and Chhatre (2000) reinforce this argument by stating that the trade and environment literature indicates that when a country eliminates some of its internal pollution, it has to allocate the required resources. Such measures shift productive capabilities from internationally tradable goods to goods that cannot be traded. As a result, in the presence of pollution control, import and export levels are expected to be lower than the level they would otherwise be.

However, a considerable part of the literature appears not to have found support for either of the above mentioned approaches. Jaffe et al. (1995), as well as Harris et al. (2002), argue that only few studies have produced evidence that environmental regulations or control costs could significantly explain the pattern of trade between countries. Hence they contend that environmental costs appear to have no real impact, neither negative nor positive, on foreign trade.

2.3.3 Competitive advantages in trade through environmental externalities

Siebert (1974) shows that a country which is richly endowed with the resource 'environment' will export commodities with a high pollution content. His study also found that the relative abundance or scarcity of environment between countries was a determinant of price differences between them. Therefore, environmental factors could define comparative advantage of countries through environmental endowment.

In the same spirit, Siebert (1992) analyses the interaction between national environmental endowment and competitiveness. He argued that a country with fewer environmental attributes would export less pollution-intensive commodities and vice versa. His analysis shows that a small country lacking environmental protection measures would produce more pollution-intensive commodities, and that the state of the country's environment would decline as a result. However, if the country put environmental measures into place, its competitiveness in pollution-intensive commodities would decline. This would lead to a reduction in exports of pollution intensive commodities and overall trade.

Interestingly, Siebert also argues that the same set of premises led to different results if the observed country was large. In this case, after protection measures are implemented the comparative advantage of the large country would be reduced. This could result in decreasing exports of high-pollution goods, which in turn may lead to an increase in the price of the polluting commodity on the world market.

Bommer (1999) investigates the question whether relocation was always caused by reduced competitiveness at home. Using a signalling approach, Bommer shows that industrial relocation may happen for purely strategic reasons. Some of the results in the study were rather surprising, for instance the finding that the probability of strategic capital flight increased with the amount of capital in question. Even more counter-intuitive, Bommer concluded that strong environmental interest groups helped to avoid strategic relocation, as their presence raised the cost of strategic ambitions. This is because environmental interest group pressure makes 'dirty' technology, which Bommer holds necessary for mimicking, less attractive than other technology available.

2.3.4 Spatial implications of the environment-economy trade-off: location theory

A number of literature contributions use partial equilibrium models to assess the short- and long-run effects of environmental externalities on trade. Taking air pollution as example, Baumol (1971) and Baumol and Oates (1988) argue that less developed countries may specialise in pollution intensive products in anticipation of economic growth. This strategy could increase their exports without adding to their employment or real earnings.

Through trade, environmentally harmful production may be transferred to countries with relatively lax environmental standards, so-called pollution haven countries. Contributions by Pething (1976), Siebert (1977), Yohe (1979) and McGuire (1982), put forward the theoretical arguments which provide a framework for the so-called *pollution haven* hypothesis. This notion states that countries may receive economic gains in exchange for the degradation or depletion of their natural resources. The argument therefore implies that trade undercuts existing environmental protection laws. Furthermore, trade issues would also affect the design and functioning of international environmental agreements.

By modelling non-cooperative games between regions, Markusen et al. (1993) demonstrate that environmental policy could determine plant location and market structure. Ulph (1994) extends the model, and shows that the importance of environmental policy in terms of its impact on location decisions appeared much greater than in earlier estimates. Competition between the two governments in the game to restrict pollution will result in highly restrictive policies and low levels of pollution and trade. Ulph and Valentini (1997) show that under certain circumstances, environmental regulation can affect relocation decisions of industries between countries. In a later article, Ulph and Valentini (2001) note that competition for location could not generally be presumed to lead to greater environmental dumping than competition for market share with fixed locations. Thus, competition between non-cooperative governments can be greater when legislators set environmental policies *after* firms decide where to locate.

There are two basic approaches to trace the link between the stringency of environmental standards and industry location. One concept evolves around pollution havens and the notion of industrial flight from areas with stringent environmental regulation. The other approach is the industrial specialisation hypothesis, which centres on investigating whether environmental regulation influences foreign direct investment decisions (Wilson et al. 2002).

In a theoretical context, Wilson (1996), Ulph (1997), Rauscher (1994; 1997), and List and Mason (2001), among others, present a number of scenarios under which local environmental regulations may reasonably race to the bottom. Fundamental to these theoretical models is the assumption that capital flows respond adversely to more stringent environmental regulations (Jeppesen et al. 2002). Cumberland (1979; 1981) considers governmental strategies under the assumption of pure competition to alter environmental standards, arguing that regions are likely to relax them to attract industry. He concludes that this competition would result in too low a level of environmental quality.

In the context of developing countries, Wheeler (2001) challenges the notion of environmental legislators racing to the bottom for five reasons. First, pollution control was not a critical cost factor for most private firms. Second, low income communities penalised dangerous polluters even when formal regulation was weak or absent. Third, rising income strengthened regulation. Fourth, local businesses controlled pollution because pollution abatement reduces costs. Fifth, large multinational firms generally adhered to OECD environmental standards in their developing-country operations.

Markusen et al. (1995) develop a two-region model under conditions of imperfect competition. They conclude that if the disutility resulting from industry pollution was high enough, the two regions would compete by increasing their environmental taxes or standards until the polluting firm was driven from the market. Alternatively, if the disutility from pollution was not as great, the regions will usually compete by undercutting each other's pollution tax rates.

However, empirical studies have produced mixed evidence regarding the notion of pollution havens. Tobey (1990) reports that a qualitative variable describing the stringency of environmental controls in 23 countries failed to contribute to net exports of the five most pollution intensive commodities. Low and Yeats (1992) conclude that on the one hand pollution-intensive industries account for a large and growing share of exports in the total manufacture of exports in some developing countries between 1965 and 1988. On the other hand, however, they note that this share decreased in developed countries. The studies of Xu (1999; 2000) focus on bilateral trade and environmental standards. They find no evidence that a country with stricter environmental standards had lower exports of pollution-intensive goods.

Walter (1974a) and Leonhard (1988) also find little evidence to support the assertion that pollution costs have influenced location decisions of multinational firms. Based on firm-level data on location choice and pollution abatement costs in the United States, Levinson (1996) indicates that there was limited evidence of industry flight towards pollution havens. One reason for this appeared to be the fact that firms which had plants in several U.S. states followed the most stringent environmental regulation in all locations. Markusen (1997) concludes that stringent environmental regulations would give multinational companies little incentive either to increase production or to relocate.

In the context of India, Mani et al. (1997) argue against the hypothesis that businesses might choose locations in response to differences in the stringency of environmental regulation across jurisdictions. Looking at the investment patterns of multinational corporations in four developing countries, Eskeland and Harrison (1997) find almost no evidence that investors in developing countries are fleeing environmental costs at home. Instead, they noted that their evidence suggests that foreign-owned plants are less polluting than comparable domestic plants.

By contrast, Henderson (1996; 1997), Gray (1997), Kahn (1997), Keller and Levinson (1999), as well as Becker and Henderson (2000) report much stronger evidence in favour of the hypothesis that environmental regulation affects the location of new firms. Coefficients of the environmental regulation variables were often significant and negative. For instance, in Henderson (1996), the two measures of environmental regulation are significant and negative in seven out of nine regression models.

Lucas et al. (1990) suggest that the implementation of progressively strict environmental regulation in OECD countries may have led to significant migration of pollution intensive industries. In a study that investigated industry location decisions of new firms in West Virginia, List et al. (1990) show that regulatory expenditures per manufacturer and location decisions were inversely related. This finding was confirmed in a later study by List and Co (1999). The investigation of Smarzynska and Wei (2001) also produces supporting evidence for the industry flight hypothesis using a firm-level dataset for 25 transition economies.

Finally, some literature contributions provide possible explanations for the inconclusive empirical picture. Gray (1997) notes that empirical evidence of industrial flight towards pollution havens was less clear than one might expect. He argued that one reason might be that firms generally want to locate in large markets, yet polluted areas may exactly offer the opposite, i.e., shrinking markets. In consequence firms may rather be driven away from pollution havens than attracted to them.

Grossman and Krueger (1992; 1993) argue that one of the reasons for the difficulties in finding statistical evidence that supports the notion of pollution havens or industrial specialisation may lie in the fact that are overshadowed by a number of dominant determinants. They conclude that endowments like physical and human capital, or investments are much more powerful factors in determining a country's trade pattern. From their meta-analysis of 11 empirical studies, Jeppesen et al. (2002) note that foreign firms investing in the United States appear to be more influenced by environmental regulation than their domestic counterparts.

Emphasising the policy implications of the debate in a study about the effects of environmental regulation in regional and global context, McGuire (1982) concludes that concerning local environmental damage, relocation of polluting industries was desirable from an efficiency standpoint. Differential regulations transfer polluting production to regions of low utility cost. The study also found that for inter-country pollution, unilateral regulation was inefficient and ineffective.

Wilson et al. (2002) show that, if country heterogeneity was accounted for, more stringent environmental standards may imply lower net exports. They argue that environmental regulation could therefore affect export competition. Based on their results, they argue that the so-called industrial specialisation hypothesis appeared to hold, according to which lax environmental standards could lead to specialisation in pollution-intensive industries by creating greater accessibility for industries to air and water resources.

In conclusion, a number of contributions seem to support the theoretical notion of a direct link between pollution performance and the reduction of competitive advantages in trade. Further theoretical extensions on this link established that, in consequence, location decisions of firms could be affected. However, the empirical evidence on the issue appears mixed and inconclusive.

2.3.5 Synergies between environmental performance and regional development

Regional embeddedness

Golub (1998a) argues that society, governments and private sector actors could mutually benefit from environmental performance, as strong environmental regulation would strengthen the competitiveness both of the regions and of the enterprises (Porter 1991; Dooley and Fryxell 1999). By applying the best available techniques for the environment, firms could both improve the quality as well as the efficiency of their production, because they would strive to produce their goods by using as few natural resources as possible. Furthermore, firms could publicly show their commitment to the welfare of the region. In other words, through their commitment to environmental performance, private sector actors could demonstrate their regional *embeddedness* (Grabher 1993).

Regional development agencies should support this creation of environmental partnerships by explaining and propagating the mutual benefits of environmentally sensitive ways of doing business to the private sector (Perrons 1992; Gibbs 1998; Swain and Hardy 1998). If the flow of information was efficient and mutual trust contributed to the creation of a common agenda between all parties involved, enterprises might be convinced that regionally responsible action could indeed be beneficial for their business perspectives. Granovetter (1985) argues that firms could thus be encouraged to alter their business philosophy in such a way that "*economic action must also be seen as social action*".

Welford and Gouldson (1993) develop this idea further. They claim that the implementation of integrated environmental management systems could be a means towards the creation of a comparative regional advantage. Such a management system could consist of a negotiated and mutually agreed set of policy instruments, such as environmental taxes, pollution control, and the institutionalised exchange of environmentally relevant information. It may be based on co-operation and mutual commitment of both the private and the public actors, who would jointly set up a regional environmental partnership (Biekart 1998). According Biekart, regions and firms could both profit from this scheme, since environmental management systems would contribute to ensure high environmental and product quality standards. This advantage could also be marketed, through the environmental certification or regional branding of the goods produced (Taschner 1998; Golub 1998b).

Ecological modernisation

Approaching environmental competition from the perspective of economic and societal development, the theory of ecological modernisation goes one step further. This concept is discussed, among others, by Simonis (1989), Spaargaren and Mol (1991), Weale (1992), Jänicke (1992), Gouldson and Murphy (1996), Hajer (1996), and Jänicke et al. (1997).

Its basic notion suggests that policies for economic development and environmental protection can be combined with synergistic effect. Hence ecological modernisation promotes the application of stringent environmental policies as a positive influence on economic efficiency and technological innovation. This argument challenges the neo-classical idea of an ecological market failure.

> *Economic theory suggests that without government intervention the lack of a regime of clear and enforceable property rights leads to the over-exploitation of common property resources and the under-provision of public goods. In seeking to prescribe an economically efficient response to market failure, the suitability of various policy instruments in different situations is continually assessed. However, while neo-classical economics suggests that market failure is at the root of environmental degradation, many political theorists suggest that it is the combined inability of the market to allocate environmental resources efficiently and of the government to respond efficiently that is to blame (see, for example, Panayotou 1992) . [...]*
>
> *Notwithstanding the importance of market and government failures, modern economies cannot be characterized by such an obvious division between the market economy on the one hand and the regulating state bureaucracy on the other hand. Instead, blame for the impacts of market and government failure is more accurately ascribed to the failings of those alliances between the common interests of industry and government that direct the formulation of policy (see Jänicke 1986). Consequently, it is neither the failure of the market nor of government but the failure of the state (meaning the bureaucracy-industry complex) that is at the root of the environmental malaise (see Anderson 1994).*
>
> Gouldson and Murphy (1996: 12)

Proponents of the ecological modernisation theory argue that it is ultimately the institutional, technological, and cultural inertia that restricts the ability of the state to correct this market and government failure, and thus to adopt proactive environmental policies. To overcome this inertia, they put forward a number of 'policy themes'. First, governments should intervene to combine environment and economy for further economic development. Second, environmental policy goals should be integrated into other policy areas. Third, alternative and innovative policy measures should be explored. And finally, the invention, innovation and diffusion of new clean technologies would be essential.

Gouldson and Murphy (1996) note that, in order to achieve these themes, state and market institutions need a driver causing a wish to address the issue (problem pressure), the capacity for innovation in both state and market institutions (innovative capacity), and the ability to strongly institutionalise environmental policy over a long period (strategic capacity).

There are empirical studies in support of the notion of ecological modernisation. For example, based on an analysis about the impact of pollution regulation on technological innovations, Similä (2002) highlights the importance of environmental regulation to foster the diffusion of innovations, particularly with respect to end-of-pipe technologies.

The literature around ecological modernisation theory appears to provide a basis to support the claim that economic development may be linked with less pollution. Considering that the concept of ecological modernisation is based on the notion of socio-economic development, one might argue that this theory is quite independent from conventional Environmental Kuznets Curve theories.

In conclusion, there appear to be two distinct theoretical bases that put forward the notion of a positive link between the economic or socio-economic development state and the pollution performance of a country. The majority of empirical contributions on the issue, however, seem to cast some doubt on the validity of this claim.

2.4 Concluding remarks

One of the objectives of chapter 2 was to illustrate that there is no overarching or unifying theory on the economic or welfare cost of pollution performance. Looking at the example of climate change politics, Bernard and Vielle note that

> *Measuring the welfare cost of climate change policies is a real challenge, raising difficult issues of micro- and macro-economics: cost benefit analysis on the one hand, foreign trade and international specialisation on the second hand. At the domestic level the possible existence of distortions, in particular in the fiscal system, may either increase or alleviate the welfare cost of a climate change policy, as illustrated by the debate on "double dividend".*

Bernard and Vielle (2003: 199)

The second goal of this chapter was to present a line of argument that ends with the insight that environmental competition is theoretically possible, and indeed to be expected if regulators behave rationally by seeking competitive advantages over each other.

The following points present a summary of some theoretical predictions which concern the impact of strong pollution performance on economic performance. In order to see how well these predictions fit with our empirical findings, we will return to them at the end of this study.

- **Pollution reduction is linked to a fall in production**. This prediction is based on the notion that pollution is inherent to economic production and consumption.
- **Pollution reduction narrows the scope to exploit competitive advantages**. This prediction is based on notions put forward by theories around environmental externalities and trade.
- **Pollution reduction is indirectly associated with the creation of barriers to market entry**. This prediction is based on the idea that rents from environmental regulation may be unevenly distributed among competing industries or firms.
- **Pollution reduction is indirectly associated with the creation of employment.** This prediction is based on the notion of a double dividend resulting from pollution taxes, as well as on the possible impact of pollution performance on industrial production and competitiveness.

2.5 The contribution of this thesis to the literature

This thesis is a contribution to the literature on the trade-off of environmental performance and economic competitiveness. It will take the form of a quantitative comparative analysis.

To this end, the first objective of this study is to develop a proxy for environmental performance, which will be a pollution performance indicator. Before the background of pollution indicators already documented in the literature, this indicator will be constructed within a relative framework, that is, the European Union. In other words, the pollution indicator captures the relative performance of one country with respect to the average of the reference system. Moreover, the quantitative nature of the indicator allows us to compare the performance of a large number of countries over a long period.

The large majority of literature contributions on the trade-off between environmental performance and the economy focus on the situation in the United States due to much better data availability. This study, on the other hand, focuses on the European Union before the last round of accession, that is, on the EU 15. Few studies have attempted to do so, in spite of the fact that the EU makes a highly interesting case study for a variety of reasons. First there is free movement of capital among the EU countries, and hence ongoing competition among member states. Second, environmental policy is among the top issues on the European political agenda, which should increase the relevance of scientific research aimed to understand the consequences of environmental competition. Third, and maybe most importantly, the EU is an entity which is still under development in terms of political and economic integration. For this reason, it seems interesting to capture the development of a policy field that has potentially important implications on both the political as well as on the economic situation of the EU's member states.

Last but not least, the quantitative set-up of our analysis allows to assess the applicability of two fundamental theories in the area of environmental competition to the case study at hand: On the one hand, the conventional economic and location theory, which predicts a negative link between pollution performance and economic competitiveness, and the Porter hypothesis on the other hand, which is based on the notion of positive implications of environmental regulation through spill-over effects.

3 Data: Dependent and Independent Variables

The following chapter sets the foundation for the subsequent regression analysis, in which the relation between pollution performance and chemical industry competitiveness is tested. However, before arriving to that point, the first part of the chapter, section 3.1, will provide an introduction to the actual subject of the comparative analysis, that is, the chemical industry in the European Union. After that, section 3.2 will provide details on a range of indicators which will later be used as independent variables in the regression analysis. Obviously, since pollution performance will be the lead explanatory variable of this study, that indicator will be highlighted in considerable depth.

3.1 The dependent variables: EU chemical industry performance

3.1.1 What do we mean by chemical industry?

In general, the terms 'chemical industry' and 'chemical industries' are used synonymously. This may not seem a big issue, but to the author's best knowledge, the chemical sector is probably the only industry class which can be addressed both in singular as well as in plural form. Why is that?

The reason seems obvious: it is not quite clear whether the chemical sector is one industry or in fact a cluster of more or less similar industries. This ambiguity is rooted in the historical development of the business. Few other industries have such a long history of technological progress, which resulted in the development of increasingly independent sub-sectors (for example, organic and inorganic chemistry), and few industrial sectors occupy such central function in modern economies.

Definition

The smallest common denominator across all firms in the sector is that chemical industries produce their products exclusively or primarily by the conversion of substances (Fleischer et al. 2000). The goal of chemistry, in this definition, is the substitution of natural substances, or the creation of new substances.

This can either be achieved by the conversion of natural substances, or by the synthesis of organic or inorganic base materials. Practically, chemical industries combine organic or inorganic materials from the earth with heat, air, and water to make chemicals to be used by other chemical producers to make other chemicals, or by other industries to make a broad range of products that are used in everyday life.

Industries whose treatment of substances is done exclusively by (or connected with) physical processes, such as mixing, emulsifying or extracting, are also often considered to be part of the chemical industry (Fleischer et al. 2000).

Approaches towards the classification of chemical sub-sectors

There are several basic approaches to break down the chemical sector into sub-sectors. First, one could differentiate certain chemical industries by their production volume or the added value their transformation processes generate. The resulting classification into bulk chemicals and speciality chemicals is a fundamental criterion with, as we shall see later, a number of important practical implications.

Bulk chemicals are high quantity and low value-added products characterised by low differentiation. By contrast, speciality products such as dyes, paints, food additives, and photographic material are more differentiated and sophisticated products. Closely related industries, such as the pharmaceutical sector, could also be counted as speciality chemical industries. Typically, speciality chemicals are produced in lower volumes than bulk chemicals, and sold for higher prices (Cook and Sharp 1992; European Commission 1998d; Cesaroni et al. 2001).

Second, an alternative way to differentiate chemical industries is by asking whether they produce intermediary or finished goods, hence the distinction between basic chemistry and parachemistry. According to the definition of the Federation of the Belgian Chemical Industries (1999a), basic chemical products are commonly intermediary goods or simple bulk consumer goods. Petrochemical goods, plastics and synthetic rubbers make up the class of basic organic chemical goods. By contrast, acids and alkalis, their derivatives as well as minerals and metallic salts are basic inorganic products.

Parachemistry, on the other hand, comprises chemical consumer products, industrial chemicals, and agricultural chemicals. The group of consumer products contains paints, vanish, inks and colours, wood-protection products, pharmaceuticals, soaps, detergents and cosmetics. Among the parachemicals for industrial use are gases, glues, oils, explosives, dyes, biocides and cleaning products. Parachemicals for agricultural use are compound fertilisers, phytopharmaceutical products, and some biotechnological goods.

Third, one could also differentiate chemical industries by the position they take in the production chain. Within this system, the chemical production chain covers the transformation of raw materials via primary industries and chemical industries into products that meet consumer needs. The most common raw materials for chemical industries are oil and gas, minerals and agricultural raw products. Following that logic, there is the group of primary (non-chemical) industries, the cluster of basic chemical industries, and the class of advanced chemical industries. One proponent of such a classification is the European Chemical Industry Council (CEFIC 2000a).

Primary industries process raw materials. Thus, refinery of crude oil and gas yields petrochemical primary products. Crushers and renders turn agricultural raw products into oleochemical primary products.

The chemical industry processes those primary products further through a sequence of hierarchical production steps. One major production sequence covers the transformation of oil and gas into petrochemical products, which can then be used as primary material for plastics and polymers, which may in turn be used as primary products fibre or transformer production. A second important production sequence involves the transformation of minerals into inorganic bulk chemicals, such as acids and alkalis. These are then used as primary material for speciality and fine chemistry (e.g., coatings, adhesives, photographic products), or pharmaceuticals. Finally, agricultural raw products are turned into oleochemical products, which are then processed further into detergents or cosmetics.

Classification of chemical sub-sectors

At this point it should be apparent that there is no method to differentiate chemical sub-sectors that is in itself methodologically superior to others. All three approaches mentioned above appear to suit a certain perspective on the issue well, all are intuitively useful. However, this situation bears a great disadvantage: in practice, this spells the lack of a coherent standard to classify chemical industries, both within the chemical sector (what sub-sectors are there?) as well as vis-à-vis other industrial sectors (are primary industries, such as refineries, part of the chemical industry?).

Table 1 illustrates that problem. It is a comparison between different chemical industry classification systems. On the one hand, it represents the chemical sub-sectors as defined by one of the most widely used industrial classification standards, NACE rev. 1. On the other hand, it shows how a range of other institutions with considerable expertise in the area of chemical industries solve the problem. Column ‘a’ follows the method used by the European Commission (1998d). This approach clusters chemical industries by product groups. Column ‘b’ corresponds to the above mentioned approach of the Federation of Belgian Chemical Industries (1999). Finally, column ‘c’ shows the chemical sub-sectors according to the European Chemical Industry Council (CEFIC 2000a).

Table 1 Comparison of different chemical industry classifications

NACE Industrial Classification					(a) Petrochemicals	(a) Specialities	(a) Life Science	(a) Inorganics	(a) Fertilizers	(a) Man-made Fibres	(a) Industrial Gases	(b) Basic Chemistry	(b) Parachemistry	(c) Primary Industries	(c) Primary Chem Ind: Oil & Gas Products	(c) Primary Chem Ind: Inorganic Bulk Chemicals	(c) Primary Chem Ind: Oleochemical Products	(c) Secondary Chem Ind: Speciality & Fine Chemistry	(c) Secondary Chem Ind: Petrochemicals	(c) Secondary Chem Ind: Pharmaceuticals
24 Chemicals and chemical products	24.1	**Basic chemicals**	24.11	Industrial gases							■		■		■					
			24.12	Dyes and Pigments		■							■			■				
			24.13	Other inorganic basic chemicals				■				■				■				
			24.14	Other organic basic chemicals	■							■				■	■			
			24.15	Fertilizers and nitrogen compounds					■				■			■	■			
			24.16	Plastic in primary form	■							■		■					■	
			24.17	Synthetic rubber in primary forms	■							■		■					■	
	24.2	**Pesticides and other agro-chemical products**					■						■					■		
	24.3	**Paints, varnishes, similar coatings, printing inks, mastics**				■							■					■		
	24.4	**Pharmaceuticals, medical chemicals, botanical products**	24.41	Basic pharmaceutical products			■						■							■
			24.42	Pharmaceutical preparations			■						■							■
	24.5	**Soaps & detergents, cleaning & polishing preparations, perfumes & toilet preparations**	24.51	Soap, detergents, cleaning preparations		■							■				■	■		
			24.52	Perfumes and toilet preparations		■							■				■	■		
	24.6	**Other chemical products**	24.61	Explosives		■							■					■		
			24.62	Glues and gelatines		■							■					■		
			24.63	Essential oils		■							■				■			
			24.64	Photographic chemical material		■							■					■		
			24.65	Prepared unrecorded material		■							■					■		
			24.66	Other chemical products n.e.c.		■							■							
	24.7	**Man-made fibres**								■			■						■	

Classification by other Institutions

(a) European Commission (1998a)
(b) Federation of Belgian Chemical Industries (1999a)
(c) CEFIC (2000a)

The table illustrates that, especially with regard to the basic chemical sector, there is little congruence among the classification methods. At the later stages of the chemical production chain, when the production steps add higher value to the products (and hence require superior skills), the classification methods seem to converge.

The two faces of chemical industry: cost leadership vs. specialisation

In summary, all three differentiation methods point at the fact that there is a transition in the production chain from the rather simple production of bulk chemicals to the knowledge-intensive small-scale manufacture of specialised chemical goods. Typically, raw materials are turned into primary products in large-scale facilities that operate on a relatively low technological level. In each subsequent stage of production, the knowledge intensity of the operation is increasing, while the scale of the producing facilities tends to decrease.

Obviously, this implies that the individual chemical industries, which perform those distinct production stages, operate very differently and hence follow different business strategies. Arora (1997) states that large-scale low-tech facilities are likely to draw their profits from economies of scale of their production. They could require a relatively less skilled work force, as mature production processes are, more or less simply, applied.

Inversely, speciality chemical industries typically run small-scale but high-tech plants, as well as research-intensive operations. In consequence, their work force needs to meet higher requirements in terms of skills. Speciality chemical industries have to compete to stay at the forefront of technological development.

Given the very profound differences between bulk and speciality chemicals production and their different business approaches, one might wonder why the chemical industry is commonly perceived as one industrial sector. Probably the most important reason to this lies in the chemical production chain. Given their strong horizontal and vertical integration, chemical industries exhibit a marked tendency for organisational and spatial concentration (Hudson 1997). In other words, due to their dependence on each other, chemical sub-industries show a tendency to produce within the same firm, or in clusters of firms.

Implications on the competitive strategy of chemical industries

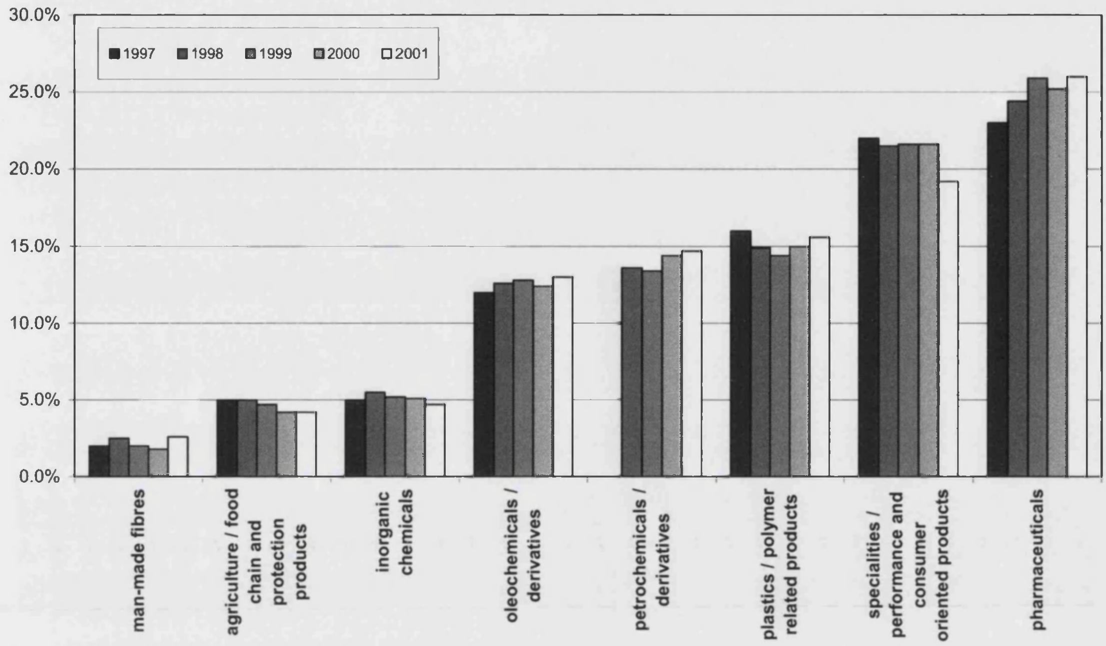
The chemical sector's heterogeneity on the one hand, and its tendency to concentrate different sub-industries in terms of organisation and space on the other hand make it a complex subject to analyse. Cesaroni et al. (2001) note that the strategies of individual chemical firms are, inter alia, dependent upon the characteristics of the branch of industry in which they operate. Product heterogeneity leads chemical firms to follow two fundamentally distinct business strategies: cost leadership on the one hand, and specialisation on the other hand. The choice of strategy depends on the product range of the chemical firm.

Firms that operate in areas characterised by price competition, as it is the case with regard to basic chemicals, are likely to opt for cost leadership strategies (Porter 1985). The empirical study by Albach et al. (1996) shows that European firms in commodity chemicals commonly focus on cost leadership strategies. Firms that pursue cost leadership typically concentrate on their core business areas. They may also choose to engage in strategic alliances with other companies in order to generate synergies. By contrast, firms in the speciality chemicals sector tend to pursue so-called specialisation strategies. Important features of the specialisation approach is the emphasis on product differentiation and customisation, and the attempt to establish higher profit margins (Cesaroni et al. 2001).

Internal structure of the EU chemical sector

Now that we have some idea about chemical sub-sectors, what is their relative importance? Figure 3 provides some information on the relative size and the development of key chemical industries in the EU between 1997 and 2001. According to data provided by the European Chemical Industry Council (CEFIC 2000a), the biggest EU chemical sub-sector in terms of production value was the pharmaceutical industry, which accounted for approximately one quarter of the overall chemical industry. The graph also reveals that the pharmaceutical sector was growing over the period. The second biggest sub-sector was specialty chemicals with around 21% of overall production volume, followed by the plastics and polymer industry with some 15% production share.

Figure 3 *EU chemical industry production by sector*



Data source: CEFIC (1998b; 1999b; 2000b; 2001c; 2002a)

In terms of sales, if one sticks to the definition of chemical sub-sectors used by the European Commission (1998d), speciality chemicals was the most important chemical sub-sector with sales that accounted for 34% of overall chemical industry sales. The next largest sub-sectors were petrochemicals with 31% and life sciences with 26%. All other chemical sub-sectors (inorganic chemicals, fertilisers, man-made fibres, and industrial gases) together accounted for the remaining 9%.

Since these three large sub-sectors make up the lion's share of the chemical sector between themselves, let us have a closer look at them. The following characterisation of the three main chemical sub-sectors is based on findings reported in the European Commission report (1998d).

Speciality chemicals

The specialities segment consists of those chemical industry firms that take raw material from the basic chemicals segment, such as petrochemicals or inorganics and convert them into 'active' ingredients for use in consumable products. The segment could be further split into fine chemicals and performance chemicals. The general characteristic of fine and performance chemicals is that they tend to be produced in small volumes. As a result, the capital intensity of this sub-sector is comparatively low.

So-called fine chemicals are active chemical compounds for use in areas such as the pharmaceutical industry. They are typically produced on the basis of exact chemical descriptions of the product required by the customer. For this reason, the main value-added by producers of fine chemistry is their internal technical knowledge to produce the product. Fine chemical companies mainly compete on the quality of their product and the cost of their production. As they have little influence on the end use to which the chemicals are put, there is a tendency for the products to behave like commodity chemicals. In effect the producers act as an outsourced manufacturing capability for the customer.

Performance chemicals on the other hand are chemical compounds produced to satisfy well-defined performance requirements. As the name implies, these chemicals are critical to the performance of the end products in which they are used. To achieve this performance the chemicals are often developed for a specific customer, with the speciality chemical producer having a strong influence in the design of the end product.

Considerable effort needs to be put into technical service to ensure that the customers keep their competitive advantage, which can be a significant cost item. As the speciality segment consists of a wide range of different products, it is characterised by having a larger number of small companies than other segments in the chemical industry. In many instances companies in the segment are based on a single product line, for which they have developed a leading technology position.

Increasingly this fragmented market of small companies is rationalising as speciality conglomerates are created. These conglomerates allow the companies to reduce the cost of common items in the business process such as branding and management systems.

Another important driver has been the reduction in the number of major customer organisations due to global consolidation. As this occurs the customers instigate world-wide supply initiatives to cut down the number of suppliers that they use, and as a result the speciality companies have had to reorganise on the same international basis. The new speciality companies are then able to develop product development partnerships with these large customers, where they add value through their ability to innovate new performance chemicals that enhance the performance of consumable products.

In spite of this consolidation however, the sector still includes a large number of small producers as the focus on product performance and the relatively small volumes mean that there are many niche markets.

Petrochemicals

The petrochemicals segment covers the areas of chemical processing that are downstream of the oil refining industry. The majority of the chemicals produced in this sector are intermediates, which are then further processed both within the petrochemical segment and also in others such as specialities.

The petrochemical sector can be characterised by its high capital intensity and large economies of scale. Petrochemical producers have to carry out very large investments in their production sites. The competition among petrochemicals takes place at global level, and is essentially cost-based. There is significant inter-regional trade between the major trading blocks Europe, North America and South-East Asia. Feedstock costs take a dominant position in the balance sheets of petrochemical producers. In other words, relative differences in the price of oil and gas primary products can offer a substantial competitive advantage.

The R&D expenditures in the petrochemical sector are relatively low in relation to sales. This seems to indicate that the petrochemical sector is relatively less knowledge-intensive that the other two major chemical sub-sectors speciality chemistry and pharmaceuticals.

The petrochemical sector is dominated by a number of very large multi-national companies. One could therefore argue that the petrochemical sector is one of the most global economic sectors in terms of company activities and markets.

There are relatively low overall margins in the petrochemical sector, which is a reflection of the cost based competitive environment, of the large numbers of producers in the market, and of the relative openness of international markets. The cyclicality of earnings appears to be high.

As a result of these industry characteristics, the petrochemical industry is currently experiencing a major trend towards industry rationalisation and restructuring.

Pharmaceuticals

The life sciences segment encompasses both pharmaceutical and crop protection products such as herbicides and pesticides. The total market is dominated by pharmaceuticals, which represented seven times the sales that were achieved in agrochemicals in 1997 (European Commission 1998d).

The dominant issues at pharmaceutical production facilities relate to quality control. As the products are for use in the body it is essential that the products do not contain impurities. The emphasis is on preventing contamination, with a large fraction of the installed equipment being concerned with cleaning systems. This requirement adds a cost that is not often encountered in other chemical sectors.

The facilities have far greater flexibility than is the case in typical petrochemical plants – little modification is generally needed to make a different product. Therefore, though individual production lines can be expensive especially when measured against volume of product produced, an investment in plant does not tie a company to producing a given product. As such, the industry can be viewed as being less capital intensive than segments such as petrochemicals. Research and development costs are extremely high, however.

As with the specialities segment, the range of possible products means that there are a large number of players in the market. Even the largest company by sales in Europe in 1998, GlaxoWellcome, only gained a 5.6 percent market share.

Rationalisation in the pharmaceuticals market is likely to be caused by the cost of new drug development. A typical new treatment takes up to nine years to develop, with many potential compounds failing to make it through to successful product. It is the costs associated with this development that are forcing companies to merge in order to achieve economies of scale.

3.1.2 Importance and performance of the chemical sector

So far, this chapter aimed to provide some insights on the nature of the chemical sector by 'looking inside' the industry. In contrast, the following pages will present the performance of the chemical sector as a whole and put it into relation with the overall economy. The underlying question that this section intends to address is why the chemical sector makes a worthwhile case study from an economic point of view. Later, section 3.1.4 will provide reasons why the chemical sector also is a meaningful object of study from an environmental point of view.

Strategic importance

Historically, the chemical sector has acted both as a focus and a motor for scientific and technological development of industrialising economies. In the late 19th and early 20th century, innovations in the field of chemistry and the subsequent development of chemical technologies have been regarded crucial national assets. They were therefore jealously guarded by national governments. For instance, Arora (1997) quotes the example of the German chemical industries, which were carefully shielded national scientific-industrial complexes until the end of World War I. This helped the German economy to outgrow other industrialising nations at the time. Later, as part of Germany's World War I compensations, its chemical industries were made to give up their technological advantage by voiding their patents, such as the rights on Aspirin. Through this, German chemical industries had lost much of strategic competitive advantage.

Naturally, the role of the sector in catalysing economic development has changed over the last century. Chemical industries have lost much of their *national* strategic importance due to the fact that they, as all other economic sectors, have been subject to globalisation. Many of the leading chemical enterprises today are huge multinational corporations that conduct their business as well as their research and development activities on an international scale (Chapman and Edmond 2000).

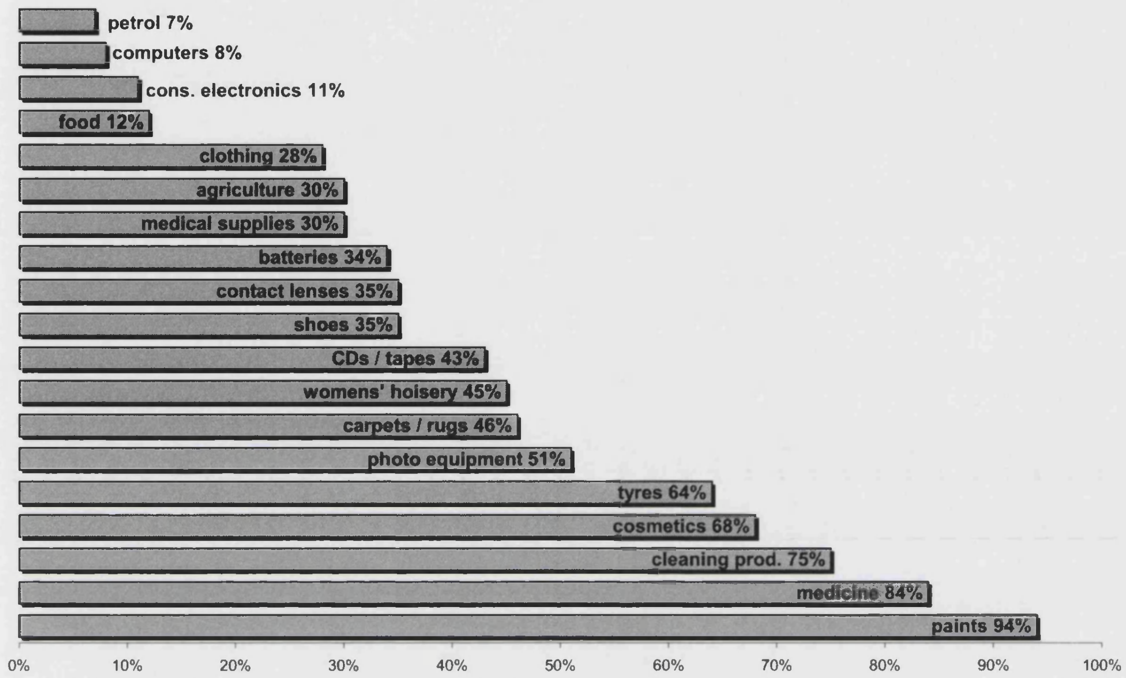
Linkages with consumers and other industries

Chemical industries produce intermediate and consumer goods that serve a wide range of consumer needs. In fact, as figure 4 shows, chemical products can be found in almost every industrial product that we use on a day-to-day basis. Civilisation, the functioning of industrialised economies and societies, seems plainly unthinkable without the amenities provided by chemical industries (Chapman and Edmond 2000).

To name but a few examples of possible applications, chemicals are used for textile production, packaging, electrical and electronic components, the automotive industry, the building industry, health care, food products, home care and personal care. Furthermore, people tend to underestimate the importance of chemicals in modern agriculture, but according to CEFIC (2001b) data, chemicals account for 30 percent of all material input in agriculture.

The chemical industry is highly forward linked with other industries both in terms of economic and technology impact and in terms of environmental issues, such as production processes or environmental techniques and services. For this reason, the chemical industry has a crucial and central role within the manufacturing sector (Maglia and Sassoon 1999).

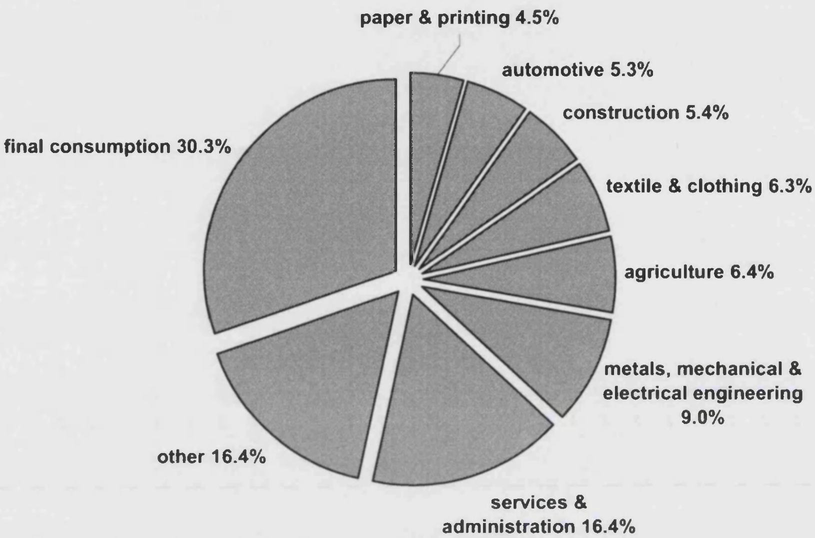
Figure 4 ***Material input of chemistry in the manufacture of selected consumer goods***



Data source: CEFIC (2001b)

More than 50 percent of chemical products are intermediate goods, which are in turn processed by a wide variety of industrial sectors. In Europe alone, more than 70,000 products like paints and coatings, fertilisers, pesticides, solvents, plastics, synthetic fibres and rubber, explosives and many others are building blocks at every level of production and consumption in agriculture, construction, manufacturing, and in the service sector (Cesaroni et al. 2001).

Figure 5 ***EU domestic consumption of chemical products by economic sector, 1995***[1]



Source: (CEFIC 2001b)

Figure 5 shows the split of domestic chemical consumption by EU economic sectors. While some 30 percent of the total chemical industry production in 1995 reached the final consumer, around 70 percent were used by other sectors of the economy: that is, agriculture, industries and the service sector.

Accounting for some 16.4 percent of total chemicals consumption, the biggest non-final consumer of chemical goods appears to be service and administration sector. Metal processing and electrical engineering, agriculture, and the textile industry were also among the most important customers of chemical industries.

[1] Percentage shares were calculated by taking into account the re-allocation of domestic consumption to downstream consumers of chemicals, self-consumption and consumption by the rubber and plastic processing industries.

As impressive as these numbers may be, one should not lose sight of another reason for the importance of chemical industries in modern economies: that is, the role of the chemical sector in transmitting innovation. Product or process improvements in the chemical sector may have positive effects in downstream industries. Since the chemical industry provides goods and engineering services to a host of other industries simultaneously, innovation in the field of chemical engineering may have the potential to create multiple spillover effects (Cesaroni and Arduini 2001; Cesaroni et al. 2001).

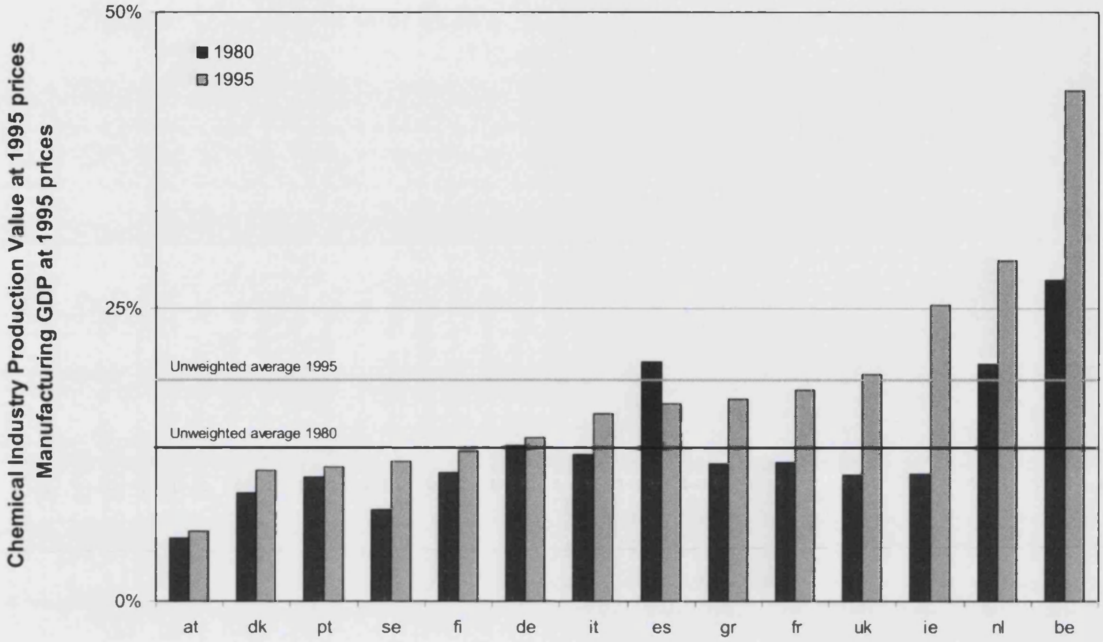
3.1.2.1 The contribution of chemical industries to GDP

The output of chemical industries makes up a substantial part of the total manufacturing production in all EU member states. As figure 6 shows, the country with the highest proportion of chemical industry production value in the manufacturing total in 1997 was Belgium. In fact, the country's industrial sector produced goods that valued more than one third of the entire manufacturing sector. The Dutch and Irish chemical industries follow with some distance. On the other end of the spectrum appears Austria, where chemical industry production accounted for little more than five percent of the total manufacturing production value.

When one considers the evolution in the percentage of chemical industry production over the observation period, it appears that some countries exhibit significant changes, while the position of the chemical sector did not change much in others. The country with the most pointed development is clearly Ireland.

The share of the Irish chemical industry in the total manufacturing production appears to have doubled between 1990 and 1997. The size of this movement is remarkable and might cause some suspicion regarding the quality of the underlying data. In response, an extensive check of various data sources on the indicator was carried out. Its findings, as well as the overall performance of the Irish economy in general and of its chemical industry in particular (Murphy 2000), appear to confirm the validity of the observation. A more detailed discussion on the plausibility of Irish chemical industry production data follows at the end of this section.

Figure 6 ***Chemical industry production value as percent of total manufacturing production***



Data Source: 1980-1996 CEFIC ESCIMO database (2001)
1997-1999 CEFIC (1998b, 1999b, 2000b)

Besides Ireland, some other EU member states seemed to exhibit significant changes: the proportion of chemical industry production decreased in Austria and the Netherlands, and increased in Greece and Luxembourg. All other EU member states did not appear to have experienced major changes.

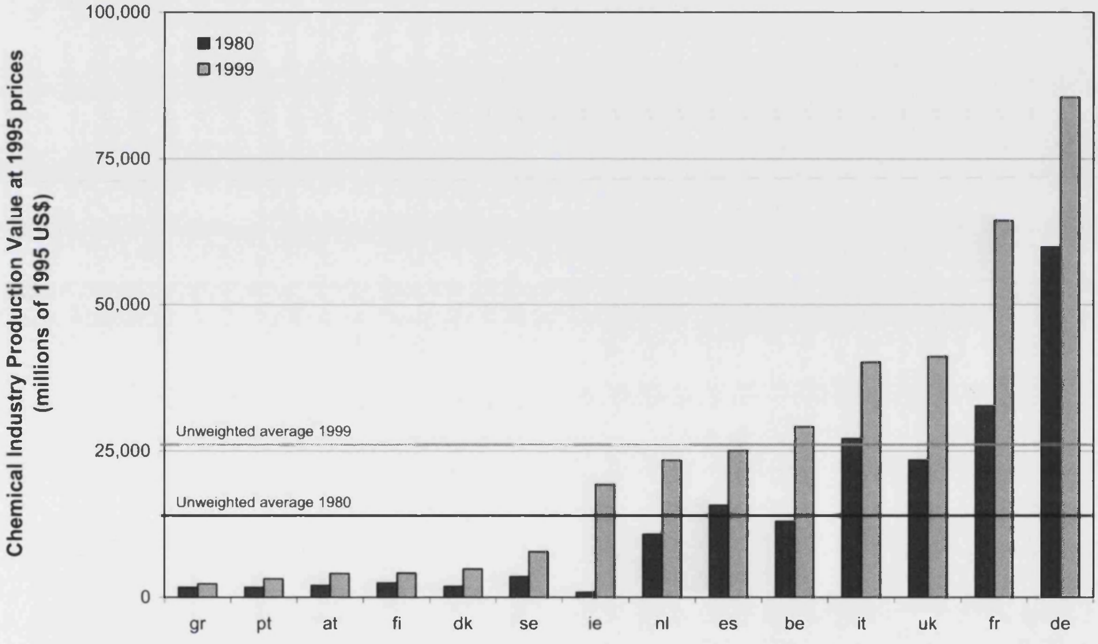
Production value as the first chemical industry performance indicator

The first dependent variable for the subsequent regression analysis in chapter 4.2 will be the value of chemical industry production in the EU member states. This data series is expressed in U.S. Dollars at 1995 prices.

The raw data for the time series was provided by the European Chemical Industry Council. CEFIC provides a range of data series on EU chemical industries as part of their comprehensive chemical industry database ESCIMO, or in the form of annual figures in their statistical yearbooks.

Among the data series provided by that organisation are data points on EU chemical industry production value; absolute data were available for the years 1997, 1998 and 1999. The figures were taken from CEFIC's statistical yearbooks (CEFIC 1998b; 1999b; 2000b). Originally, the production value was reported in €; the data was converted into U.S. Dollars using the annual exchange rates provided by U.S. Federal Reserve Bank (2000) and deflated to reflect constant prices of 1995.

Figure 7 ***Chemical industry production value (absolute)***



Data Source: 1980-1996 CEFIC ESCIMO database (2001)
1997-1999 CEFIC (1998b, 1999b, 2000b)

The remaining years 1980 to 1996 were extrapolated from a chemical industry production index, which was also provided by CEFIC as part of its ESCIMO database.[2] The base year of the index was re-calculated to 1995. Since both the index data series as well as the absolute production values in U.S. Dollars provided values for 1997, it was possible to extrapolate the missing absolute production values in U.S. Dollars (1980 to 1996) by combining the two data series. The result of this operation is recorded as table 36 in the appendix.

Figure 7 represents the production value of EU chemical industries in 1980 and 1999. The diagram shows that all European chemical sectors have increased their production volume over the observation period. It also shows that the rate of increase varied considerably across the EU.

Of the fourteen countries in the sample, the production volumes of thirteen chemical sectors grew by more or less comparable ratios. The most different evolution in chemical industry production value among the countries in this 'mainstream group' can be observed in Greece and Denmark. The smallest increase occurred in Greece with 36 percent; Denmark marked the biggest increase in chemical industry production volume with 160 percent.

Yet, the increase in production volume of the chemical sector in Ireland clearly stands out from the rest of the EU. Over the observation period, the value of chemical industry production in Ireland grew by the factor 23. While the Irish chemical sector was the smallest of all 14 countries in the sample in terms of production value in 1980, the country ranked eighth in 1999. Indeed, the production value of the Irish chemical industry in 1999 was bigger than the production of the three following countries – Sweden, Denmark and Finland– taken together.

[2] The index was labeled 'Production Index, Chemical Industry (kind-of-activity index)'. Further explanations or details on its methodology were not available. The CEFIC statistical yearbooks mention that the definition of chemical industry varies across countries. This may explain why CEFIC had to resort to its particular kind-of-activity definition of the chemical sector.

The evolution of the absolute chemical industry production value appears to be an interesting and telling dependent variable if one wants to investigate the sector's competitiveness. The production value provides a clear idea on which national chemical sector has grown most in terms of absolute output. From this angle, the outstanding increase of production value in Ireland is a remarkable fact in itself. It poses the question in what way the background for development of the Irish chemical sector differs from the rest of the EU. The regression model will test whether Ireland's chemical industry production performance is connected to the differences among EU countries with regard to taxation, fuel prices, productivity, and pollution performance.

Yet, the outstanding development of the Irish chemical industry production value also appears to hint at the fact that there are additional important aspects that might help in the interpretation of production values. It is a well documented fact that the Irish economy and its manufacturing sector in particular have grown much stronger than the European average over the observation period.

Chemical industry production value / GDP

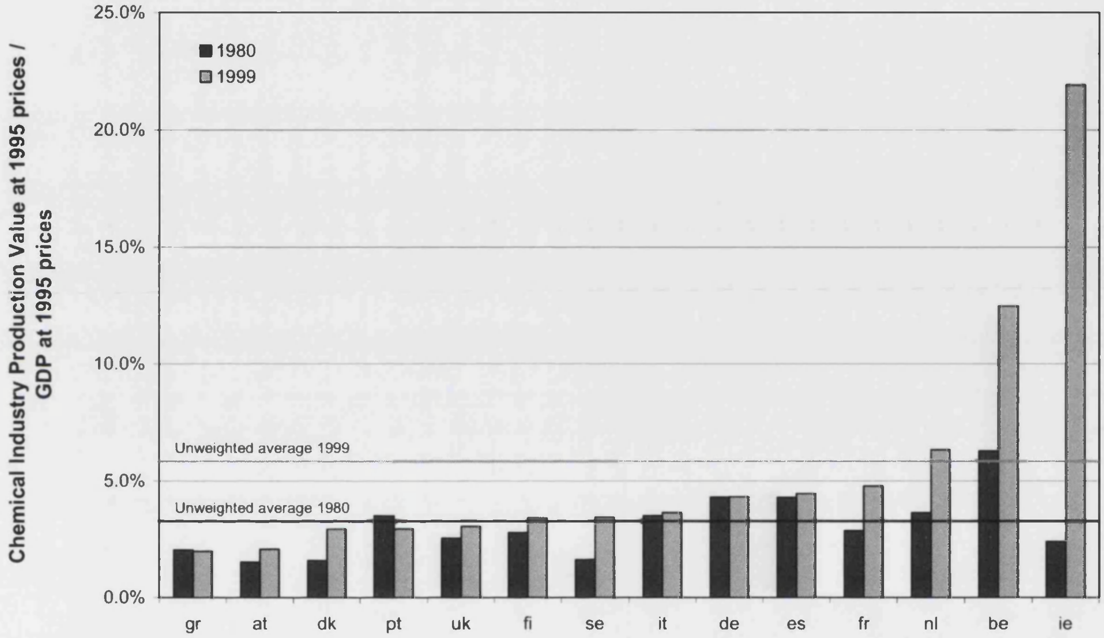
Before this background, it appears reasonable to compare the increase of chemical industry production value with the overall growth of the economy (GDP). The following dependent variable will pick up this line of argument. Therefore, as a complement to the above data set on production values in absolute terms, the second dependent variable will be the ratio of chemical industry production to GDP.

Chemical industry production value / GDP provides a distinct take on the competitiveness of the chemical sector, because it reflects developments in the production value of the chemical industries in relation to the growth of the rest of the economy. Hence, the evolution of this indicator over time shows whether the chemical industry production value has grown faster or slower than the overall economy.

The basic data on chemical industry production values is identical to the dependent variable introduced above. In addition, the production value is put into relation to national GDP data drawn from the OECD and the World Bank.

For the period from 1980 to 1996, the GDP data was taken from the OECD's National Accounts database. For the years 1997 to 1999, it was sourced from the World Bank's World Development Indicators database. The GDP figures are quoted in U.S.$ at 1995 prices. The data set is recorded as table 37 in the appendix.

Figure 8 Chemical industry production value / GDP at 1995 prices



Data Sources: table 37 in the appendix

Figure 8 represents chemical industry production / GDP figures in 1980 and 1999. The picture illustrates that in twelve of the fourteen countries in the sample the ratio was more or less at a comparable level. In 1980, Austria had 1.5 percent of GDP contributed by the chemical sector, which is the lowest ratio of this mainstream group. The highest value could be found in Germany with 4.3 percent.

In 1999, the country with the lowest chemical industry production value / GDP ratio was Greece with 2.0 percent; the Netherlands showed the highest ratio with 6.3 percent. Most countries in this group showed a moderate increase in their production value / GDP ratios; two notable exceptions were Greece and Portugal, where the chemical sector lost some of its importance compared to the overall economy.

There are two countries that do not appear to fit into the EU mainstream. First, Belgium exhibited a significantly higher share of chemical industry production value in total GDP both at the beginning and at the end of the observation period. In 1980, the production value of the chemical sector amounted to 6.3 percent of the GDP; this ratio almost doubled to 12.5 percent in 1999. The data appears to indicate that the Belgian chemical industry is much more important in the context of the overall economy than in most other EU countries.

This observation also holds true for Ireland, which is the second outlier among the EU member states. The production value / GDP ratio for the Irish chemical sector grew from 2.4 percent in 1980 to 21.9 percent in 1999.

One should note that this rise, which corresponds roughly to an increase by the factor 9 –as impressive as it may appear–, is well below the observed increase in absolute chemical industry production value in Ireland, which grew 23-fold. In other words, not only the chemical sector in Ireland grew considerably, so did the Irish economy as a whole. Yet, the growth rate of the chemical industry production value exceeded the growth of the general economy by far. In consequence, according to the data, the Irish chemical sector accounted for almost 22 percent of the country's GDP in 1999.

The correlation coefficient between the chemical industry production value in absolute terms and as a ratio of GDP is 0.15. This low coefficient indicates that the two data series are to a large degree independent. Based on this observation, the two dependent variables appear to capture different aspects of chemical industry competitiveness. The first indicator –the absolute production value– captures the increase or decrease of chemical industry output. The second indicator –the production value relative to the GDP– reflects the relative importance of chemical industry production value in the context of the national economy.

On the plausibility of the Irish production value figures

The ratio of Irish chemical industry production value to GDP appears suspiciously high. In response to this, the data series that were used for the construction of this variable have been carefully checked for consistency and plausibility, and were compared to other data sources. The data was discussed with experts of the statistical office of the European Commission, Eurostat, as well as with representatives of the Irish Central Statistics Office. Alternative data series provided by (1) the Irish Development Agency IDA, (2) the Irish Pharmaceutical & Chemical Manufacturers Federation, (3) the Irish Business and Employers Confederation IBEC, and (4) the Chemical & Engineering News, appear to show comparable proportions and evolution over time. Taking the feedback from various sources into account, there appear to be no grounds to question the validity of the data.

One possible explanation for the particularly high percentage in Ireland may lie in the fact that the definition of "chemical industry" by the Irish Central Statistics Office *includes the pharmaceutical industry*, a chemical sub-sector that appears to have had particularly high growth rates in Ireland over the last decades (IBEC 2001). This practice is, in itself, no reason to suspect that the Irish data is biased, as including pharmaceutical industries appears to be common practice across most EU member states. However, one should note that each EU member state's statistical office has some degree of liberty in defining its industry definition. For this reason, one needs to be cautious in comparing that indicator between countries. However, since the primary focus of this investigation is the evolution over time of the indicator, and since the regression analysis incorporates country dummy variables, the use of the data series may be justifiable.

According to data obtained from Eurostat and the Central Statistics Office of Ireland, the manufacturing share of GDP in 1995 stood at 26.9 percent. By virtue of this figure, the Irish manufacturing sector represented the largest share in GDP of all EU manufacturing sectors. On the other hand, the production value of the Irish chemical industries grew almost exponentially in the subsequent years from 1995 to 1999.[3] These two observations taken together may also support to the notion of such a high chemical industry production value/GDP ratio.

According to information by the Irish Pharmaceutical & Chemical Manufacturers Federation (IBEC 2001), there was a massive influx of greenfield inward development into the Irish chemical sector during the 1980s and early 1990s. 16 of the top 20 pharmaceutical companies in the world opened plants in Ireland. According to IBEC (2001: 4), the exports by the Irish chemical industry grew between 1974 and 1995 by a massive 17,974 percent. Since the early 1990s, the growth of the industry was in its majority organic, based on existing company extensions. Due to the fact that the Irish chemical industry is dominated by fine chemical and pharmaceutical companies, and taking into account that most plants were constructed after 1970, Ireland possesses a very modern high-tech chemical sector that lack some of the negative characteristics of older EU chemical industries such as massive scale intrusions on local communities and pollution problems.

[3] Note that the data points of Ireland as well as of all other EU member states were extrapolated from an index with regard to the years 1980 to 1996, and taken directly from CEFIC's Eskimo data base for the years 1997 to 1999. In the case of Ireland, there appears to be a break in the time series from 1996 to 1997. That break is probably due to a change in the definition of chemical industry. In order to assess the impact of this break, the subsequent analysis will present two sets of regression models: one including Ireland, and another one excluding the country. With regard to all other EU countries but Ireland, the extrapolated and the original data points seem to correspond well.

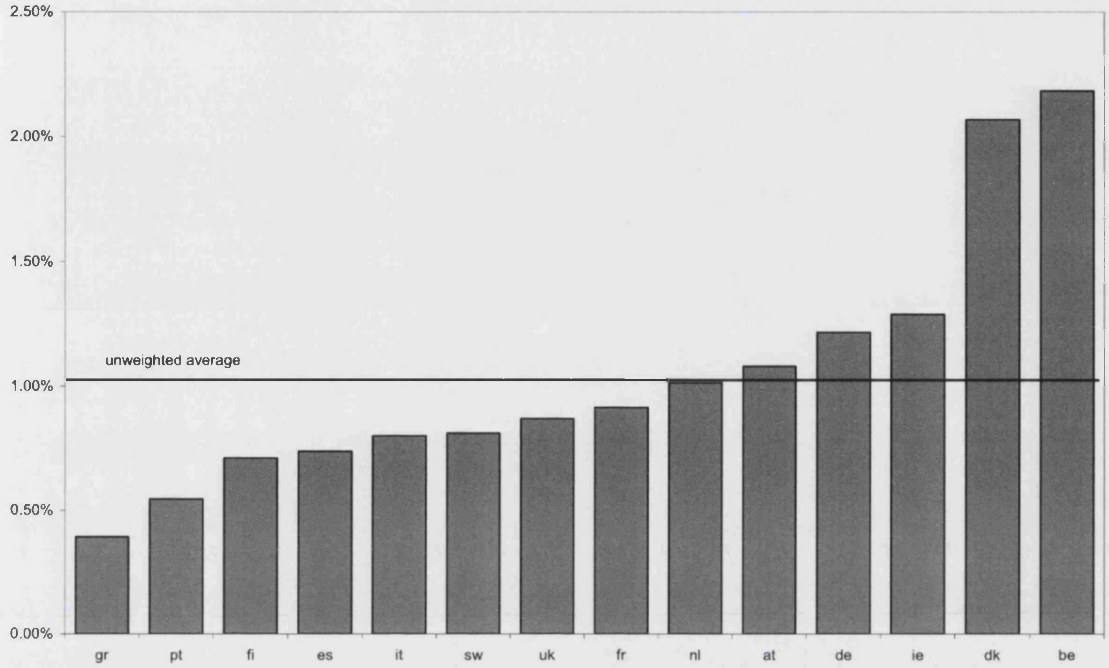
Last but not least, the strength and relative importance of the Irish chemical industry has been highlighted in a number of previous empirical studies. For example, Maglia and Sassoon (1999) point out the economic strength of the Irish chemical sector relative to other EU chemical industries, and most notably in relation to the German chemical sector. For instance, their analysis illustrates that the Irish chemical sector has outperformed the rest of the EU with regard to profitability, profit growth, and foreign direct investment. Murphy (2000: 15/16) notes that among the five leading high-tech industries in Ireland –computers, software, pharmaceuticals, chemicals, and cola concentrates– the net output per person in the chemical sector clearly surpassed the other sectors.

In conclusion, although there is no evidence that the data set on the Irish chemical industry production value is systematically or materially wrong, there may remain some intuitive doubt about whether 'they can be true'. For this reason, the subsequent regression analysis will report two sets of models: one including and another one excluding Ireland.

3.1.2.2 Chemical industries and labour markets

As figure 9 shows, chemical industries provide a significant source of employment in the European Union. In 1998, EU chemical industries provided jobs for 0.98 percent of the total workforce, compared to 0.75 percent in the United States and 0.56 percent in Japan (CEFIC 2001a).

Figure 9 Employment in chemical industries as percent of total workforce, 1998



Note: IE refers to 1997
Data sources: CEFIC (2001)
OECD / Main Industrial Indicators (2001)

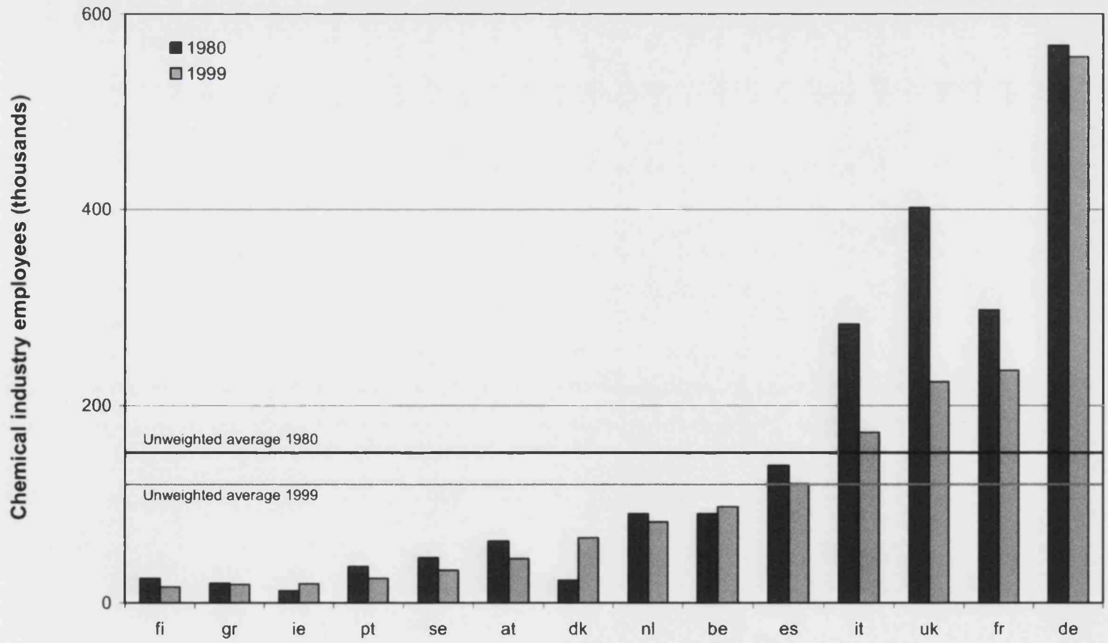
One should note that the percentage of employment to the total workforce varies considerably across EU member states. The two countries with by far the highest proportion of chemical industry jobs in 1998 were Belgium and Denmark. In both countries, the chemical sector provided employment for more than two percent of the occupied population. Ireland, Germany, Austria, and the Netherlands also exhibited more jobs in the chemical sector than the EU average. The EU member states with the lowest proportion of chemical industry employment in 1999 were Greece and Portugal, followed by Finland and Spain.

Chemical industry workforce as the second performance indicator

Given the importance of the chemical sector as employer and the socio-economic importance of job creation over the recent years in the EU, the second chemical industry performance indicator will be the number of chemical industry employees. As in the case of the first dependent variable, chemical industry employment will be used in absolute terms as well as in relation to the total employment.

The data for this indicator was obtained from the European Chemical Industry Council (CEFIC) and Eurostat. Data covering the number of employees in the national chemical sectors was provided by CEFIC as part of its ESCIMO data base. The time series was obtained through the CEFIC homepage in 2001. It is recorded in the appendix as table 38.

Figure 10 Chemical industry employees (absolute)



Data source: CEFIC, ESCIMO Database (2001)

The figures, which are represented in figure 10, suggest that in the five countries with the largest chemical sectors in the EU, i.e. Germany, France, Britain, Italy and Spain, the absolute number of chemical industry employees has decreased over the observation period. This process appeared to be especially significant in the UK, where the workforce of the chemical sector was almost cut in half between 1980 and 1999. On the other hand, the largest chemical sector in the EU, Germany, seemed to experience a much less dramatic cut in employment.

Among the fourteen countries in the sample, only three experienced an increase in chemical industry employment. These three countries were Ireland, Denmark and Belgium. With regard to Ireland and Belgium, that development appears plausible, since absolute chemical production as well as production relative to the GDP also increased significantly over the observation period (cf. figure 11).

It should be noted, however, that the very significant increase in chemical industry employment in Denmark cannot be fully explained by simultaneous increases in production volumes. The data shows that Denmark experienced a slow and relatively constant increase over the observation period, with the exception of 1987/1988 when the ratio of chemical industry employment to occupied population almost doubled.

The most likely explanation for this sudden shift may be a break in the time series between 1987 and 1988. Such a break could have been introduced by a re-definition of the chemical sector. Unfortunately, the ESCIMO data base does not provide further information that could clarify this point.

Chemical industry employment / total workforce

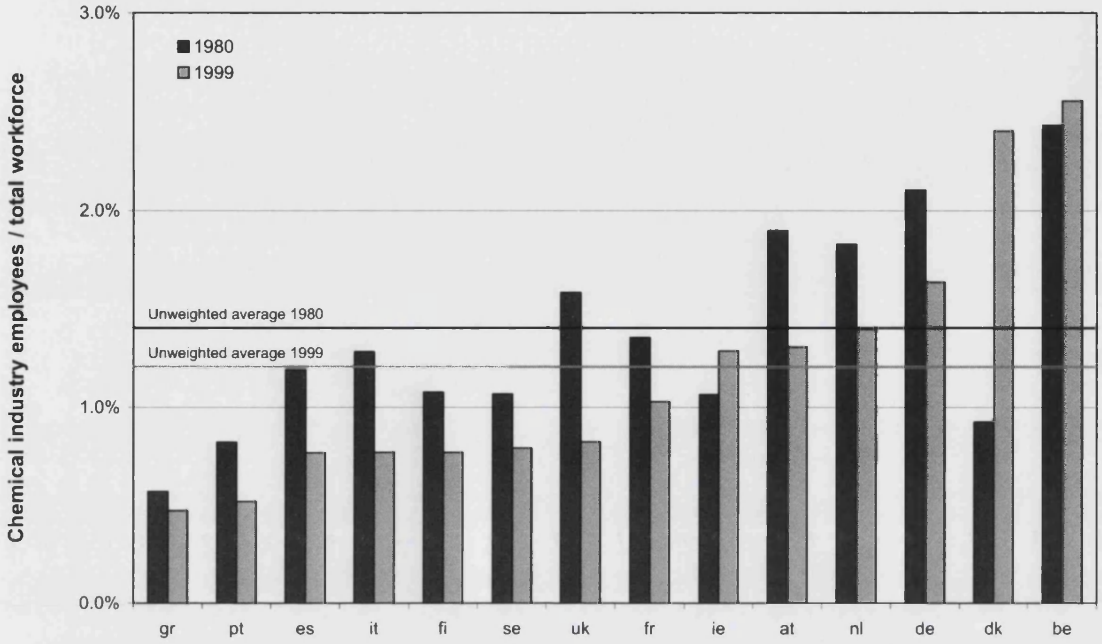
The fourth dependent variable in the regression analysis will be the ratio of chemical industry employment to the total workforce. The corresponding data on the overall workforce of EU member states[4] was provided by Eurostat as part of its Newcronos data base (2001). The original data set covers the period from 1980 to 1997. The missing years 1998 and 1999 were extrapolated as a linear projection on the basis of the available data. The final data set on chemical industry employment / total workforce is recorded as table 39 in the data appendix.

The chemical industry employment/overall workforce indicator appears useful for the assessment of chemical industry competitiveness, because it may show whether the sector has outperformed the overall economy in terms of job creation, or whether the sector has indeed provided proportionally less jobs than the rest of the economy. Inversely, in times of economic decline or stagnation, the ratio of chemical industry employees to the total occupied population could reveal whether the chemical industry lost proportionally more or less jobs than other sectors of the economy.

Across countries, the ratio could also tell something about the relative importance of the chemical sectors as employers within the national job markets. As figure 11 illustrates, national chemical industries had very different shares in the overall workforce. The highest ratio could be found in Belgium, where approximately 2.5 percent of the workforce was employed by chemical industry employers. In Belgium, this ratio increased slightly over the observation period.

[4] The data set was originally labelled "total occupied population (paid and unpaid)".

Figure 11 *Chemical industry employees / total workforce*



Data sources: CEFIC, ESCIMO Database (2001)
Eurostat, Newcronos Database (2001)

By contrast, Greece exhibited the lowest percentage of chemical industry employment relative to the total occupied population. Approximately 0.5 percent of the workforce found jobs in the chemical sector. That ratio decreased by around 0.1 percent over the observation period.

Eleven of the fourteen countries in the sample experienced a decrease in chemical industry employment in relative terms. This appears to indicate that in a majority of EU member states, the chemical industry lost some of its importance on the national labour markets. Only Ireland, Denmark and Belgium exhibited an increase in chemical industry employment relative to the total.

If one puts the chemical production value/GDP in relation to the percentage of national workforce employed by chemical industries, one may conclude that the chemical sector appears highly productive relative to the rest of the economy. For example, in the UK in 1999, the chemical sector produced goods at the value of 3.0 percent of the GDP while using only 0.82 percent of the UK workforce. This pattern appears to be generally consistent across all EU member states. However, some countries such as Belgium or Ireland exhibit an especially large difference in productivity between the chemical sector and the rest of the economy.

3.1.2.3 Chemical industries and trade

For chemical industry stockholders, one of the most relevant business figures is probably the market share of their company, as it helps to judge the competitive success of their products and their marketing. All other factors being equal, the evolution of market share could serve as a sign whether the company is offering competitive products at appropriate prices vis-à-vis its competitors. If it decreased, this might be a hint at strategic or structural problems that the company experiences on the market.

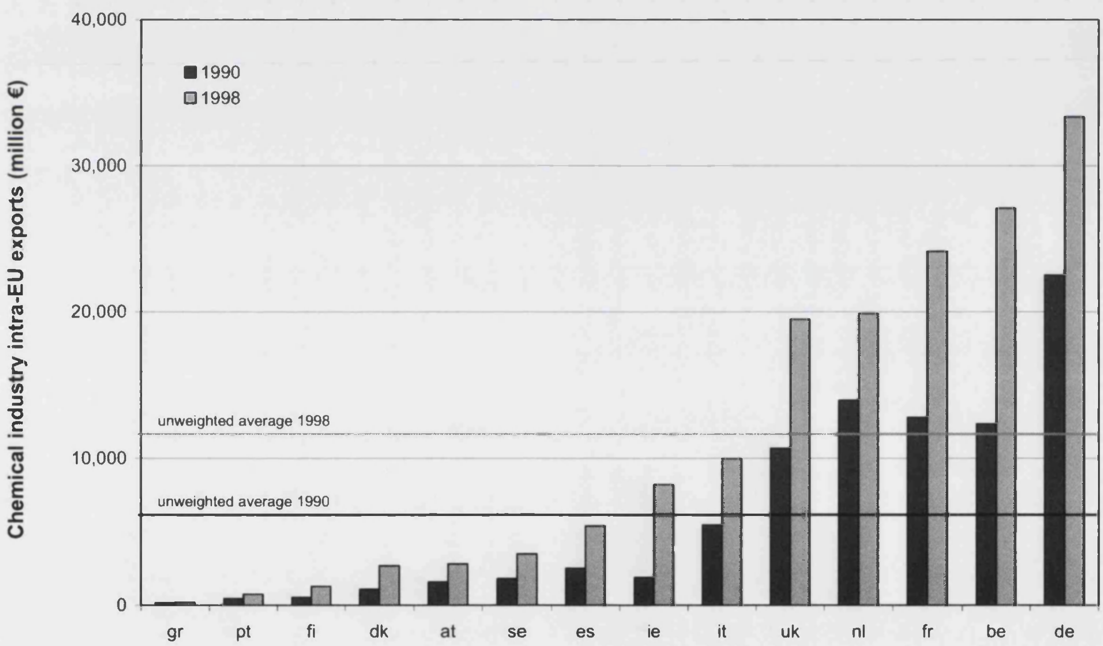
With some qualifications, a similar argument could be applied to entire chemical sectors. Obviously, one cannot simply argue that aggregate entities such as entire economic sectors would commit clear-cut strategic mistakes such as over-pricing or the like. Other factors, such as tax levels, productivity, or market size, which will be captured by the independent variables in the regression analysis, could play a role in determining the market share of economic sectors.

As this focus of the comparative analysis lies on the performance of national chemical industries relative to each other, the EU common market appears to be the most relevant reference basis. Following that logic, the best suited unit to compare the 'sales volume' of chemical sectors would have to be intra-EU exports. Hence, chemical industry intra-EU exports will serve as the third dependent variable. Again, the variable will be expressed in absolute terms and as a ratio of intra-EU exports to GDP.

According to the above argument, the evolution of intra-EU exports of national chemical sectors should tell which chemical industries had relatively more favourable structures to compete on the EU common market, and which ones had not.

Once more, the data for this dependent variable came from the European Chemical Industry Council as part of its ESCIMO data base. The data was downloaded from CEFIC's internet homepage in 2001. Unfortunately, this time series does not cover the entire observation period. Twelve of the fifteen countries in the sample had data points covering the period from 1990 to 1998.

Figure 12 Chemical industry intra-EU exports (absolute)



Data source: CEFIC, ESCIMO Database (2001)

The Irish time series relates to 1990 to 1997; the missing data point was projected on the basis of the available data points using an exponential function, which was the one fitting best to the existing cloud of observations. The Swedish data set provided information only for the period 1990 to 1994. Since the evolution of the Swedish intra-EU exports appeared to follow a linear trend, the missing values were filled in as a linear projection of the available data points. The data series is recorded as table 40 in the appendix.

Figure 12 shows that the absolute value of chemical industry intra-EU exports– measured in € million– has grown in all EU member states. The diagram illustrates that the highest increase over the observation period 1990 to 1998 took place in Ireland, where it more than quadrupled in less than a decade. The second highest growth rate was experienced by Belgium, where intra-EU exports more than doubled. With roughly 25 percent, Greece experienced the lowest augment.

Furthermore, the graph also shows relatively high intra-EU export figures for countries like Belgium and the Netherlands. In terms of absolute intra-EU export value in 1999, the two countries rank second and fourth respectively among all EU member states. As such, their chemical industry intra-EU exports are larger than the ones of Britain, Italy or Spain.

Intra-EU chemical industry exports / GDP

When one puts the intra-EU export figures in relation to the national GDP,[5] this observation becomes even more evident. As figure 13 illustrates, relative to the size of their national economies, the intra-EU exports of the Belgian, Irish and Dutch chemical industries were much higher than in the rest of the European Union member states.

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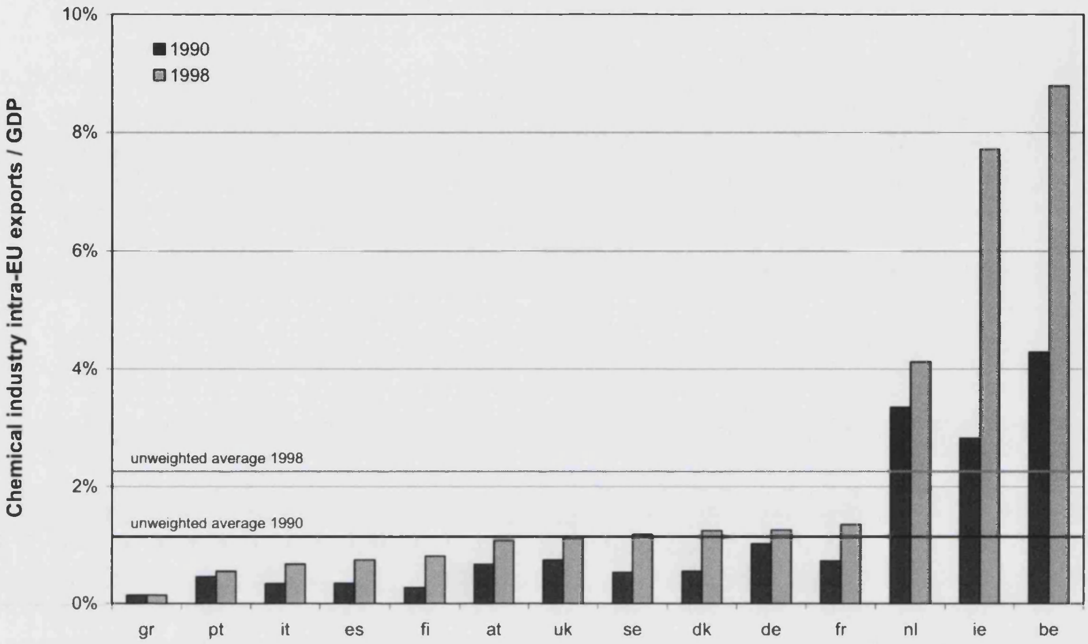
[5] The data set regarding national GDP values corresponds to the ones used as independent variable and as normalizing factor in section 3.2.2. Please refer to that chapter for details on the data source and construction of the time series.

Figure 13 Chemical industry intra-EU exports / GDP



Data Sources: Table 41 in the appendix

The share of Belgian chemical industry intra-EU exports in GDP more than doubled over the observation period from 4.3 percent in 1990 to 8.8 percent in 1998. An even more significant increase took place in Ireland, where the ratio grew almost threefold.

All EU member states experienced increases in relation to that indicator. The intra-EU exports of some chemical sectors, for example in Finland, Denmark, Sweden or Spain, grew by comparable magnitudes. However, the data also shows clearly that these raises took place on a much lower level.

3.1.3 Restructuring of the chemical sector in the European context

So far, this description of the chemical sector has focussed on two issues. The first section, 3.1.1, was an attempt to define the sector and discuss its internal structure. The second section, 3.1.2, presented a number of indicators on the economic performance of the chemical industry. The following section takes another perspective: its central issue will be to show the structural differences of the chemical industries across EU member states, and to discuss the drivers of the current restructuring processes.

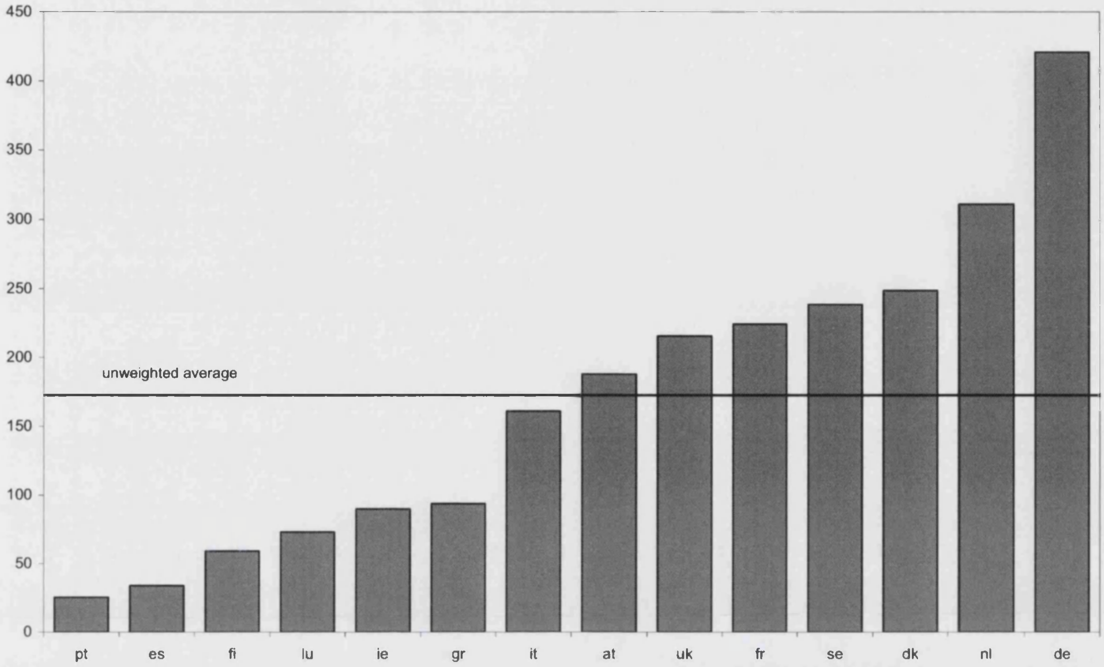
3.1.3.1 Structural differences among EU member states

Various indicators draw a vivid picture on the structural differences between the national chemical industries among the 15 EU member states. These differences could be summarised into three distinct aspects: the average size of chemical companies, the share of 'low-tech' chemical industries, and the knowledge intensity of chemical sectors.

Average size of chemical companies

To begin with, figure 14 reveals one very fundamental difference across national chemical industries: the average number of employees per chemical industry enterprise. The country with the, in average, largest chemical enterprises among EU member states is Germany, where the average enterprise size was around 430 employees in 1996. With in average more than 300 employees, the Dutch chemical enterprises appeared to be already significantly smaller in terms of enterprise size. Given the enormous size of some German and Dutch chemical industry conglomerates, such as Bayer or Royal Dutch/Shell, these numbers appear plausible. However, the German and Dutch chemical sectors exhibit a significant difference in average size relative to their counterparts in the United Kingdom and France – countries that also have a number of major chemical industry players.

Figure 14 Average number of employees per chemical industry enterprise, 1996

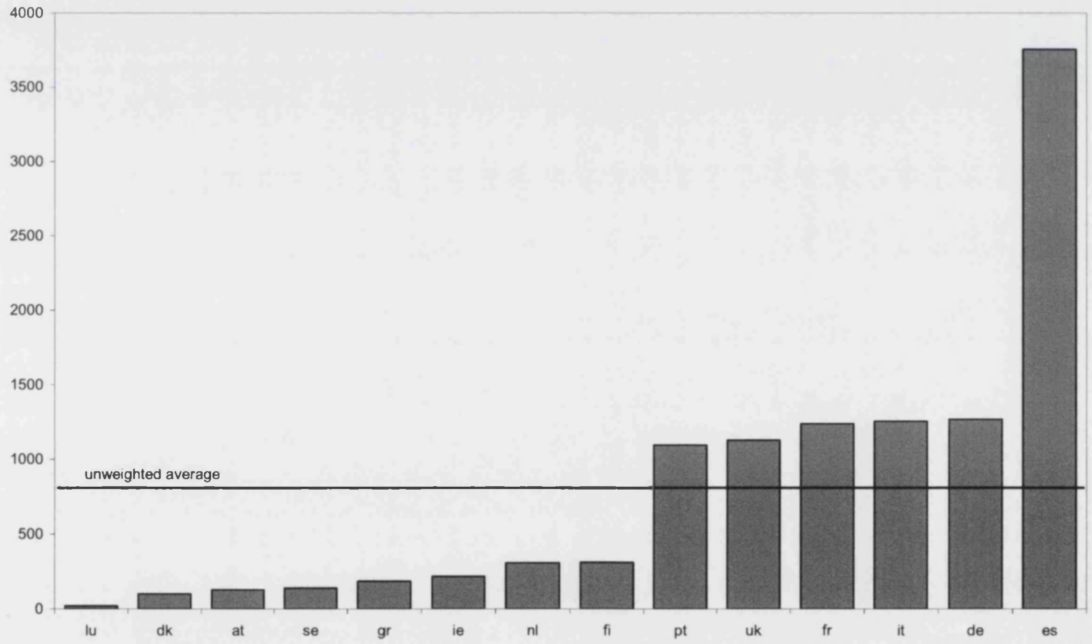


Data source: Eurostat / Newcronos (2001)

At the other extreme of the spectrum appears Portugal with an average chemical enterprise size of only 25 employees. The cluster of EU member states with relatively small chemical enterprises also includes Spain, Finland, Ireland, and Greece. This observation appears to hint at the fact that chemical firms in central and more developed EU economies tend to be bigger than their counterparts in relatively more peripheral markets. Furthermore, the data also seems to suggest that chemical firms in Mediterranean countries are relatively smaller than the EU-15 average.

Complementing the point before, figure 15 reports the absolute number of chemical industry enterprises across EU member states. Obviously, the figures should not be compared across member states, as they are not normalised. However, looking at the data, one observation could safely be made: considering the relative size of the Spanish and Portuguese economy, the absolute number of chemical industry enterprises in those countries appears remarkably high. As a result, judging from the information on the average size and absolute number of chemical industry enterprises, the two Iberian chemical sectors seem to stand out for their large number of small chemical firms, whereas the chemical sector in countries like Germany or the UK appears much more concentrated.

Figure 15 Absolute number of chemical industry enterprises, 1996



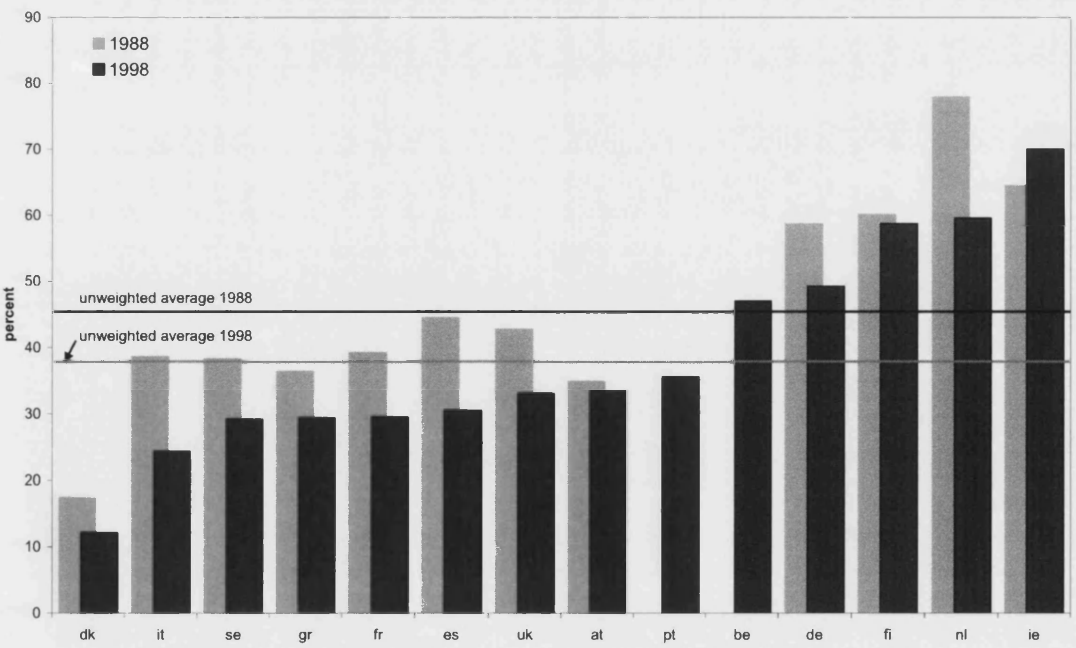
Data source: Eurostat / Newcronos (2001)

Share of basic chemical industry

Figure 16 shows the ratio of the basic chemical industry (cf. chapter 3.1.1) relative to the fine and performance chemical industries in terms of its production value. The diagram illustrates that the significance of the basic chemicals vis-à-vis the more knowledge intensive and value-added speciality chemistry varies greatly across EU member states.

In 1998, Ireland exhibited the highest share of basic chemicals, amounting to approximately 70 percent. The sub-sector also appeared to be relatively more important in countries like the Netherlands and Finland than in the rest of the European Union. By contrast, the basic chemical industry was markedly underrepresented in Denmark and Italy, where it accounted for approximately 11 and 23 percent of total chemical production respectively.

Figure 16 ***Basic chemicals production as percentage of total chemical production (basic chemistry and specialities)***



Note: DK / IE / SE refer to 1990 and 1998; AT refers to 1991 and 1998
Data source: Eurostat / Newcronos (2001)

Furthermore, the graph shows that, between 1988 and 1998, the share of basic chemicals in total chemical production shrank in most EU member states. The only exception to this trend was apparently Ireland, where, starting from an already high level, the basic chemicals sector increased its relative weight.

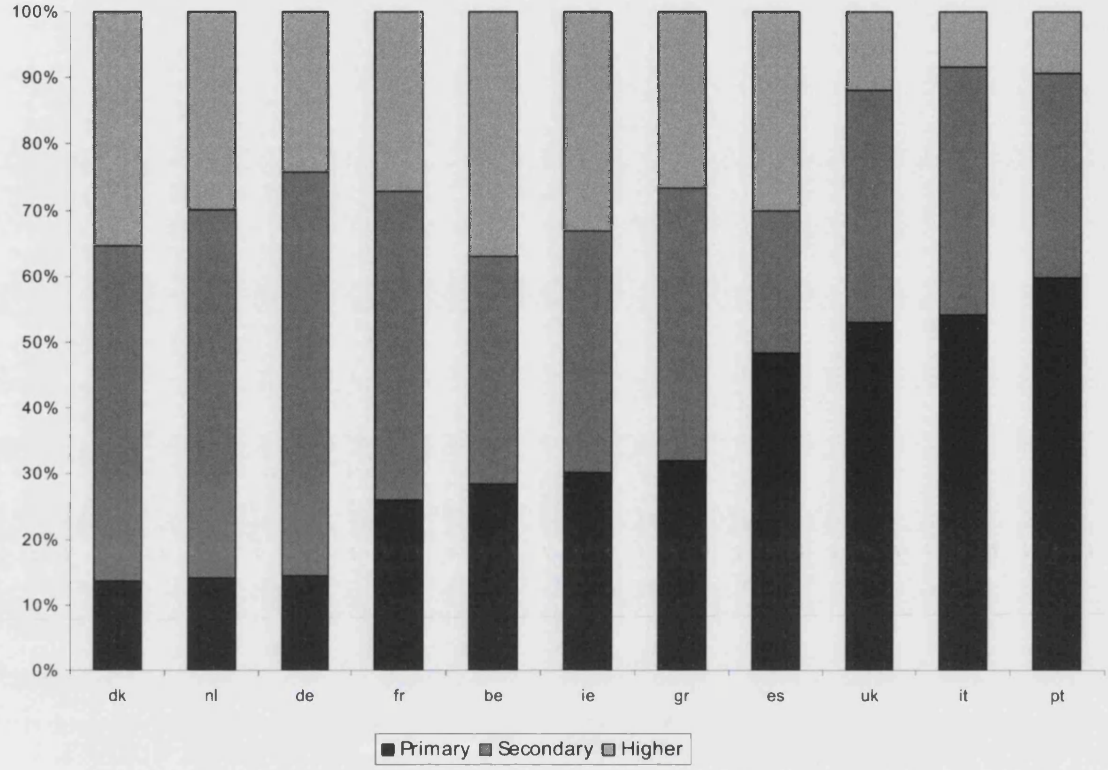
Last but not least, one interesting observation may be that the relative importance of the basic chemicals industry in the Mediterranean EU member states appears to be rather lower than EU average. This fact is surprising, since one often-heard topic about the regional distribution of chemical industries states that southern European countries had a higher share of 'primitive' basic chemical industries than northern ones.

Education of the workforce and R&D intensity

The great importance of innovation on the development and competitiveness of chemical industries is a common theme among most studies on the sector. For example, Cesaroni et al. (2001) highlight the chemical industry's long tradition in innovation and R&D activities as one key characteristic of the sector. Since its origins in the second half of the nineteenth century with British and German dyestuff manufacturers, the chemical sector appears to be science-based and science-driven. Moreover, Cesaroni et al. note that, more than in other industries, innovation in the chemical industry derives from the interaction between the academic world, individual firms, government policies, and historical events.

For this reason, the average education level of the chemical industries' workforce may provide an important insight into the competitive position and strategy of national chemical sectors. As figure 17 shows, there are significant differences across EU chemical industries with regard to the highest degree of their workforce. Judging by the percentage of employees with secondary or higher degrees, the chemical sectors in Denmark, the Netherlands, and Germany appear to have the workforce with the highest average skills. It may be worth noticing that it is exactly this group of countries that also have in average the largest chemical industry enterprises. By contrast, the chemical industry's workforce in Portugal, Italy, The United Kingdom, and Spain exhibits a distinctly smaller percentage of secondary or higher education.

Figure 17 Highest education degree of the chemical industry workforce, 1995

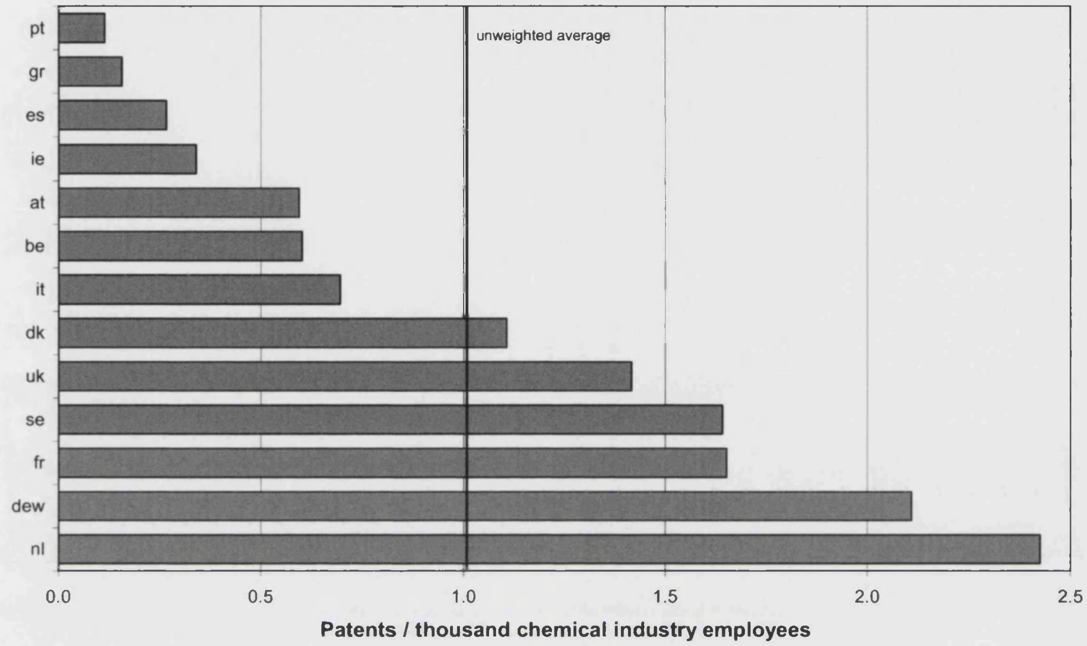


Note: PT refers to 1994
Data source: Eurostat / Newcronos (2001)

As noted above, the production of bulk chemicals is regarded as less R&D intensive and sophisticated than the production of speciality chemicals (Cook and Sharp 1992; Cesaroni et al. 2001). Based on this notion, one might expect that chemical sectors with a high percentage of basic chemicals production have a lower-skilled workforce.

However, comparing the information contained in figures 16 and 17, there is no apparent relation on first sight. In the case of Denmark, the observed relationship corresponds to what one might expect: the chemical sector with the lowest percentage of basic chemicals production does indeed have the highest-skilled workforce. Yet, with regard to Italy, the expected relationship does not hold. Italy's chemical sector exhibits the second lowest percentage of basic chemicals production as well as the second lowest-skilled workforce. An inverse but similarly counter-intuitive relationship appears to apply to the Dutch chemical sector as well.

Figure 18 ***Patent applications (organic & inorganic chemicals) / chemical industry employees, 1995***



Data Sources: patent applications – Eurostat / Newcronos (2001)
Chemical industry employees – CEFIC Eskimo database (2001)

Among the possible explanations for this inconclusive relationship could be the fact that chemical production, irrespective of whether it regards basic or speciality chemicals, requires a generally high average level of skill. Furthermore, mentioned before, due to the integrated chemical production chain, basic and speciality chemicals production facilities are commonly found in close neighbourhood to each other. The workforce of a chemical plant typically operates both types of chemical production. Finally, it may be that the type of chemical production is not the key determinant to the average skill of the chemical industry workforce, but the R&D intensity of the national chemical sectors, as illustrated in figure 18.

3.1.3.2 Drivers and trends of the restructuring

Global market pressures

On a global level, according to the European Commission (1998d), the key challenges to European chemical industry restructuring lie within the large diversified groups that have commodity petrochemicals as a significant component of their current portfolio. These are the main product areas where Europe is under the most global competitive pressure, and where the legacy of prior government and national influence has created a structure most disadvantaged compared to the key competitor region of North America.

First, Europe has had too many producers of the main individual petrochemicals and polymers, a legacy of national focus in prior years. The cost burden that this imposes is reducing rapidly, as restructuring occurs in response to global competitive pressures. The European Commission expects this process to continue as the global pressures are currently still intensifying.

Second, different chemical industries are – appropriately – responding in different ways to the competitive environment. All are seeking to reduce unit costs and improve customer focus, but radically different business models are being adopted to achieve this. These range from a complete shift to different businesses (e.g. ICI), to adherence to the virtues of integration and a broad portfolio while attacking costs at all levels (e.g. BASF). In between, many companies are choosing to focus upon the core products and competencies that they see as representing their strongest competitive position. There is as yet no compelling financial evidence that one of these models is broadly superior to others. It is clear however that some form of strong and continuous improvement is essential by all European producers, in the face of global pressures.

Third, European-based companies achieve lower levels of profitability than their US-based competitors. This reflects the lower margins in their home markets, to which all producers are heavily linked. Possible reasons for this lower profitability in European operations include relatively lower plant scales, excessive numbers of producers, less access to advantaged feedstock situations, higher unit labour costs (and lower labour flexibility), higher utility costs (particularly electric power and natural gas, due to cost and competition factors), higher capital costs (mainly due to higher unit labour costs), less effective integration and logistics, and less homogeneous markets.

Some of the above points are being addressed by industry consolidation and restructuring; some are being improved by the move to increasingly unified markets and price transparency; utility and feedstock costs may be addressed by efforts for de-regulation and more supplier competition. Most of the labour-related (including capital cost) penalties are due to national legislation, which varies widely between countries, with Germany normally cited as having the biggest comparative disadvantages.

Fourth, there are efforts among EU chemical sectors to improve their industry structure and efficiency via "strategic alliances". However, full mergers among major chemical companies are still rare in the EU, due to the reluctance of national governments to 'sell out' their strategic economic sectors. This practical constraint prompts chemical industries to seek "virtual restructurings" as second best solutions in terms of the desired competitiveness improvements (European Commission 1998d).

The competitiveness gap between American and European chemical industries

Maglia and Sassoon (1999) highlight a number of 'competitiveness gaps' between European and U.S. chemical industries, which causes the profitability of the European chemical sector to be steadily lower than U.S. levels. First, the capital intensity of EU and U.S. chemical is different, with EU investment levels being consistently lower. In the 1990s, capital spending as a ratio of sales increased in the U.S., after a short decrease during the recession of the early 1990s. By contrast, capital spending levels remained low and constant among EU chemical industries over that period.

Second, Maglia and Sassoon argue that a comparison of the human capital structure shows that the EU chemical industry is a disadvantageous position: the average skill level of an employee in the American chemical industry is higher than in Europe. In addition there is a greater polarization of skills in the U.S. chemical sector: in the U.S. there seems to be a relatively higher proportion of higher level skills and low skills, whereas in Europe, employees with intermediate skills represent a greater proportion.

Further reasons for the competitiveness gap may also be found in structural differences between the two chemical sectors. According to Maglia and Sassoon (1999), the European chemical industry differs from the American one with regard to a relatively higher concentration of low-value-added activities, and thus in relatively lower overall productivity. Furthermore, the production scale of European chemical industries is relatively smaller and hence their ability to exploit economies of scale.

Finally, Maglia and Sassoon also report that R&D expenditures relative to sales volumes are higher than in the U.S., but doubt that this indicator is a valid proxy for the competitiveness of R&D efforts. The findings of Fleischer et al. (2000) appear to lend support to this suspicion, as they report that EU chemical industries exhibit lower R&D productivity, lower patent productivity, less polymer patents, and a lower number of new chemicals notifications than their U.S. and Japanese counterparts.

With a special emphasis on knowledge-related drivers of the current restructuring processes, Cesaroni et al. (2001) state that knowledge linkages become increasingly important. First, networks play an ever more important role in the business. Second, the division of labour at the industry level between chemical companies and technology suppliers is increasing. Third, the depth of the relationships between chemical producers and their customers is growing in order to better specify the characteristics of chemical products. Finally, knowledge and R&D take an ever more important role as a source of competitive advantage and growth.

Competitive pressures within the EU

Obviously, these competitive pressures do not only exist on a global level, but should also have an impact on the competitive position of national chemical sectors within the EU. In fact, there is ample literature evidence of an increasing competition between EU chemical industries (for example, Pintelon and Geeroms 1997; BDI and VCI 1999; VCI 1999). The completion of the EU common market may have played an important role in this development: the removal of trade barriers and the harmonisation of tax regulations, labour laws and environmental laws may have levelled the playing field among national chemical sectors.

As Chapman and Edmond (2000) illustrate, there has been a profound restructuring process among chemical industries in the European Union since the mid-1980s. In fact, a significant proportion of the worldwide merger and acquisition activities in the chemical sector took place within EU, where it was stimulated by economic and political integration. Moreover, Chapman and Edmond argue that through the restructuring process in the EU chemical industry, a systematic transfer of corporate control took place, as companies based in northern Europe acquired a substantial number of competitors in southern Europe.

3.1.4 Evidence on the link between chemical industries and pollution performance

Given the variety regarding its constituting sub-sectors, its economic importance, and the size of its structural differences across EU member states, it should be apparent at this point why the chemical industry makes a fascinating subject to this comparative analysis. However, the last, obvious, and maybe crucial question that remains to be answered concerns the logical link between the activities of the chemical sector and pollution performance.

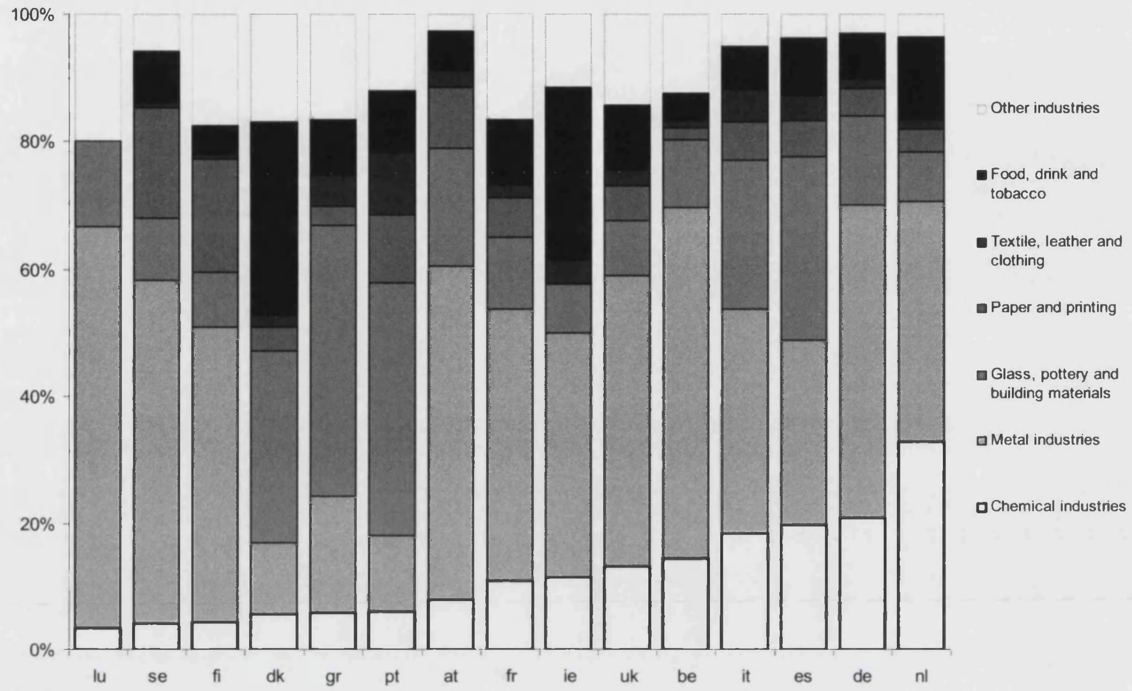
3.1.4.1 The impact of chemical industry activity on pollution performance

Capturing the impact of chemical industry activity on pollution is not as straight forward as it may look, and there is only limited 'hard evidence' in the form of chemical industry pollution statistics, especially with regard to the EU. There are two reasons that may explain this difficulty. First, pollution statistics for EU member states do not disaggregate pollution sources below the level of the manufacturing sector. Secondly, even if data on the pollution output of the chemical industry was available, the question remains whether this information would actually represent its 'true' pollution performance.

The reason for this, at first sight paradoxical, twist lies in the nature of the chemical industries' business. Most economic activities produce pollution as a by-product of their actual products or services. Many of the chemical industries' products, however, are pollutants in themselves. One good example for this 'indirect' form of pollution is ammonium nitrate (NH_4NO_3), which is produced by agrochemical firms in great quantities as a high-nitrogen fertilizer. Once the fertilizer is applied to the soil, a part of it is decomposed into ammonia (NH_3) –which is an air pollutant. For that reason, statistics show that by far the biggest source of ammonia pollution in Europe is the agricultural sector. This observation is certainly correct, but also somewhat superficial. Depending on the perspective one chooses, both farmers and the agrochemical companies could be considered producers of ammonia pollution. Moreover, one could reasonably expect that any change in ammonia pollution performance at macro level (for example, through tougher environmental standards) would affect both farmers *and* agrochemical producers.

However, even its own right (that is, even if one only looks at the pollution that is generated as a by-product of chemical production), the chemical industry is a significant polluter. As an example, figure 19 shows the percentage of chemical industry CO_2 emissions relative to the total CO_2 emissions of the industrial sector.

Figure 19 Major industrial CO_2 sources, 1996



Data: Eurostat / Newcronos data base (2001)

The diagram illustrates how dependent the share of chemical industry emissions is on a country's industrial structure. Notwithstanding, the chemical industry generally appears to be one among several major industrial polluters – along with the metal industry, the cement producing industry (which, in the classification used in the graph, forms part of the glass, pottery, and building materials industry), and the paper and pulp industry.

Literature evidence

Most empirical studies that specify the quantity of chemical industry pollution focus on the situation in the United States. The reason for this appears to be rather simple –the U.S. Environmental Protection Agency compiles a toxic release inventory that is far more detailed in terms of source location as well as industrial classification than any reference for the European Union. However, there seems little reason to suspect that the pollution contribution of American chemical industries may vary greatly from its European counterpart –at least not with regard to the order of magnitude.

Using data from the U.S. toxic release inventory (TRI) system, Wilson et al. (2002) note that the chemical industry emitted 33 percent of all industrial discharges to the air, water and soil in 1993. They note that this finding is consistent with historical data, as the chemical industry consistently surpassed other industries in TRI releases.

Also based on data from the U.S. Environmental Protection Agency, Domazlicky and Weber (2004) report that chemical industries accounted for 36% of all toxic releases generated by the U.S. manufacturing sector in 1993. Between 1988 and 1993, toxic releases by the chemical industry declined by 7.1% annually, which is less than the annual decline of 8.6% in the overall manufacturing sector. Over the same period, the chemical industry share in manufacturing pollution abatement operating costs increased from 22.9% to 24.8%.

Earlier empirical literature has used various definitions as to which industrial sectors may be considered pollution-intensive. One approach to this issue is to look at the amount of money industries have to spend to reduce their pollution, i.e., their pollution abatement cost. This approach formed the basis for the study by Grossman and Krueger (1993) who investigate the environmental intensity of industrial sectors by the ratio of pollution abatement costs to the total amount of value added. Low and Yeats (1992) follow the same rationale of using abatement costs as a measure for pollution intensity. They defined pollution-intensive goods as products of industries that incurred abatement costs of approximately 1 percent or more of the total value of sales. Based on this definition and using data for 1988, they identified four industries as pollution-intensive: iron and steel, metal manufacturing, cement, and agricultural chemicals.

Along the same line of argument but using different thresholds, Tobey (1990) considers industries pollution-intensive when direct and indirect abatement costs were equal or greater than 1.85 percent of total costs. By this standard, metal mining, primary nonferrous metals, pulp and paper, primary iron and steel, as well as the chemical industry were found to be pollution-intensive sectors. In a later study, Wilson et al. (2002) also followed this definition.

Technological advances in the area of chemical processes

Cesaroni and Arduini (2001) note that innovation in the chemical sector is especially relevant to environmental innovation as a whole, as European environmental patents are mostly developed by the chemical industry. They argue that the European chemical industry has the leadership role in the development of environmental technologies. Furthermore, chemical industries and chemical engineering firms are very active in offering their technologies to provide environmental products and services. In this sense, the impact of environmental innovation in the chemical sector could be multiplied through applying them in other industrial sectors.

Over time, the pollution intensity of chemical industries has been shown to decrease due to technical progress. Chemical engineering is constantly developing new production processes, especially in the field of new chemical reaction concepts. Such technical advances could have the potential to create environmentally friendlier processes in the middle and long term. Pereira (1999) notes that the long-term goal is to develop chemical processes, which posses a raw material utilisation rate of 100 percent. In other words, those processed would use the entire material input to produce new goods. With time, Pereira expects a shift in the focus of chemical production, from mere compliance with environmental standards to a point where environmentalism, like safety, was fully integrated into the corporate culture.

3.1.4.2 The impact of environmental performance on chemical industry activity

There are a significant number of literature contributions that report findings about the impact of pollution performance on the economic performance of chemical industries. One broad strand of contribution focuses on the cost of pollution reduction, which could take the form of capital expenditure. A second group of contributions investigates the impact of environmental regulation on chemical industry innovation and productivity changes. Finally, there is a branch of investigations on the impact of environmental performance on various other indicators of chemical industry competitiveness such as exports or FDI.

Pollution abatement expenditures

Based on data provided by the U.S. Department of Commerce (1993), the chemical sector had the highest pollution abatement capital expenditures (*PACE*) of all industries in the sample. Hence, changes in environmental regulation could imply significant changes in the cost structure of the industry. For example, in 1991, the pollution abatement costs in the production of chemicals and allied products accounted for 12.9 percent of total capital expenditures. That figure was even higher for related chemical sectors, such as the production of paper and allied products, where PACE made up13.7 percent of total capital expenditures, and petroleum and coal production. In that industry, pollution abatement costs accounted for 24.8 percent of total capital expenditures. The average PACE of all U.S. industries was 7.5 percent (Jaffe et al. 1995).

Moreover, the United States Department of Commerce (1993; also Jaffe et al. 1995), also published data on the percentage value of pollution abatement cost (PAC) relative to the total value of shipments in 1991. The figures appear to vary greatly across industrial sectors. The mean percentage in the sample was 0.62 percent; in other words, the U.S. industrial sectors in the sample spent on average 0.62 percent of the value of their shipments on pollution abatement measures in 1991. However, some industrial sectors in the sample spent significantly less on pollution abatement than the average. For example, printing and publishing invested a mere 0.15 percent an PAC, followed by machinery (0.24 percent), furniture and fixtures (0.32 percent), electrics and electric equipment (0.42 percent), rubber and plastics (0.44 percent), and fabricated metal products (0.54 percent).

Among the industries that were found to have high pollution abatement costs were paper and pulp production (1.27 percent), chemicals (1.38 percent), primary metal products (1.51 percent), and petroleum and coal products (1.8 percent). In conclusion, this data seems to indicate that the chemical industry spends more on pollution abatement than most other industrial sectors.

Productivity

Based on their analysis covering various industrial sectors and the period between 1970 and 1980, Barbera and McConnell (1990) show that environmental regulation has had a modestly adverse impact on chemical industry productivity. According to their results, the total percentage change in productivity due to environmental regulation amounted to approximately -10 percent. As a result of this, total factor productivity appeared to decline due to environmental regulation.

Berman and Bui (1998) examine the effect of air quality regulation on the productivity of some of the most heavily regulated manufacturing plants in the United States, the oil refineries of the Los Angeles air basin. They used direct measures of local air pollution regulation in this region to estimate their effects on abatement investment, and compared the sample to refineries not subject to local environmental regulations over a period between 1979 and 1992.

Despite the high costs associated with the environmental regulations, productivity in the Los Angeles Air Basin refineries rose sharply during 1987-1992, a period of generally decreasing levels of productivity in the refinery business in other regions. The evidence appears to show that stringent air quality regulation could increase productivity levels in petroleum refining. Berman and Bui conclude that abatement investments are productive, as productivity levels appear to increase due to air quality regulation.

Based on their study on productivity growth among chemical industries at U.S. state-level over the period 1988-1993, Domazlicky and Weber (2004) state that they found no evidence that environmental protection measures reduced productivity growth. At the same time, they conclude that their result is inconsistent with the Porter hypothesis that tougher regulation foster innovation.

Furthermore, according to the estimates of Domazlicky and Weber (2004), the U.S. chemical industry lost some U.S. \$540 million in 1988 from regulatory constraints and threats of lawsuits which kept it from being able to freely dispose of pollution. This figure increased over time to U.S. \$ 1,112 million in 1993. These numbers appear to correspond in broad terms with the estimate of Konar and Cohen (2001), who found pollution-related losses of U.S. \$ 989 million in 1989 related to U.S. chemical industries.

Innovation

As an empirical example of the advantages to the development of innovative technology, Porter and van der Linde (1995) refer to the Scandinavian pulp and paper producers. This industry was among the first to introduce new environmentally friendly production processes. Porter and van der Linde argue that, as a result of this leadership position, pulp and paper equipment suppliers have made major gains on the world market for innovative bleaching equipment.

Focussing on quality management and pollution reduction, Sheridan (1992) reports the example of Dow Chemicals, one of the first global chemical industry producers to institutionalise the link between quality improvement and environmental performance. Statistical process control mechanisms were established to serve two purposes. First, they reduced the variance in production processes. Secondly, they also helped to lower the amount of waste generated through these processes. After Dow Chemicals implemented these innovative measures, quality management and pollution control has become common practice in the chemical sector. Today, it is standard industry practice to concentrate the responsibility for environmental, safety, health and quality issues in one joint department.

Overall competitiveness

The European Commission (1998a; 1998b; 1998c) issued a major study on the impact of environmental regulation on the competitiveness of the EU chemical industry. The study concentrated on six factors of competitiveness: net exports of the EU, the share of the EU in world chemical production, outward and inward direct investment, gross fixed capital formation, annual turnover, and labour productivity. The main variables to proxy the strictness of environmental regulation were pollution abatement costs and expenditures (PACE), as well as the ratio of PACE to value added by the chemical sector.

The study asserts that, despite facing stricter environmental regulation, the chemical industry has performed better than other manufacturing sectors. Based on this finding, the investigation team concluded that business decisions of the chemical sector are not based on the strength of environmental regulation.

On the other hand, based on correlation estimations between the six competitiveness indicators and the proxies for environmental regulation regarding Germany and the Netherlands, the study found no correlation between the competitiveness of the chemical industry and the severity of environmental regulation.

Wilson et al. (2002) conducted an empirical study on the impact of environmental regulation on exports of five pollution-intensive sectors in 6 OECD and 18 non-OECD countries. The industrial sectors under observation include metal mining, nonferrous metals, iron, steel and chemicals. Wilson et al. concludes that, if country heterogeneity is accounted for, more stringent environmental standards imply lower net exports.

An empirical study on the effect of the laxity of environmental regulation on FDI by Xing and Kolstad (1996; 2002) shows that environmental regulation is a highly significant determinant of FDI into chemical industry and primary metals. Thus, lower foreign direct investment seems to be related to the strictness of environmental regulation. On the other hand, the analysis also concludes that environmental regulation is insignificant for variations in FDI into less polluting sectors.

Concluding remarks

As the evidence from the data and the literature shows, there are numerous sources of evidence of a two-way relationship between environmental performance and chemical industry activity. Both observations are important for the theoretical basis of this study.

On the one hand, the link between chemical industry activity and environmental performance, and in particular pollution performance, is a fundamental assumption to the following analysis. Unfortunately, the data evidence on this point in the context of the EU is far from comprehensive. There are, however, two lines of argument that could make up for the lack of a clear statistical proof. First, and most importantly, there is the analogy with the situation in the United States, where numerous studies have produced empirical evidence on the chemical industry-pollution link. Second, chemical industry products contain or are –by their nature– pollutants which might be released to the environment by subsequent users. For this reason, statistics that show only the amount of chemical industry pollution which is generated as a by-product of their production process, might fall short of the sector's real contribution anyway.

On the other hand, there is a host of literature evidence on the link between environmental performance and the different aspects of chemical industry performance. Since this study is also a contribution to this arena, its results will have to be reflected with those earlier observations.

3.2 *The independent variables*

> *One of the most important effects of increased state involvement in environmental affairs will be the new competitive disparities it will produce. There are already significant geographical differences in environmental costs in such industries as petroleum, chemicals, and pulp and paper. [...]*
>
> *In addition to labor availability, access to raw materials, and energy costs, state environmental regulation is likely to become a key criterion in siting new production facilities in the future.*
>
> Christensen (1995: 150)

The choice of independent variables is one of the critical steps that determine the quality of a regression model. The independent variables need to meet a number of criteria. First, they should have an intuitive and straight forward causal relation to the dependent variable. Second, they need to be sufficiently independent from each other in order to minimise the risk of collinearity. Yet, taken together, the explanatory factors have to account for as much of the evolution of the dependent variable as possible. Last but not least, the data sets need to be available, consistent and comprehensive.

Given the research question at hand, pollution performance will obviously be one of the independent variables; the other explanatory factors need to be chosen according to the requirements mentioned above.

The first question to be answered here is which factors other than pollution performance may have an impact on the economic performance of EU chemical industries. One of the most obvious places to look for answers is certainly the chemical industry itself.

The European Chemical Industry Council (CEFIC) has published a series of position papers, called *Barometers of Competitiveness*, in which it highlights and analyses issues that it believes are of importance to the competitive position of the European chemical sector. Over the last years, this series included position papers on the following topics:

- the profitability and productivity gap between the U.S. and European chemical sectors (CEFIC 1998a)
- the tax burden on EU chemical industries (CEFIC 1999a)
- regulation as an inhibitor of innovation (CEFIC 2000c)
- the EU policy towards chemicals' regulation (CEFIC 2001b)

Three of the independent variables introduced below aim to reflect these issues. First, the variable 'taxes on import and production' aims to proxy different taxation systems or taxation levels. Second, the variable 'productivity of the manufacturing sector' should serve as a proxy for differences in labour productivity between national chemical sectors. Third, 'fuel price', reflects one very important cost factor for chemical industry production. Moreover, the GDP evolution of EU member states will serve as a technical independent variable to account for the size of the economy in regression estimations where the dependent variables are expressed in absolute terms.

Finally, and most important in the context of this thesis, the lead independent variable will be environmental performance. The following sections will provide a comprehensive overview on each of these independent variables. Let us start by looking at environmental performance, which will be proxied by relative pollution performance.

3.2.1 Air pollution performance

3.2.1.1 Methodology

Every quantitative analysis on the pollution performance of states or of industries has to deal with considerable practical and methodological challenges. Most of them may be summarised by two keywords – availability and suitability.

At first sight, the issue of data availability appears to be the more obvious and immediate difficulty. The scarceness of consistent, comparable data series that cover sufficiently large periods of time is a well documented problem in the field of environmental analysis (Jahn 1998). Yet, in practice data suitability may pose the much more demanding obstacle to the work of empirical researchers. In particular, questions on data significance, data comparability, and the selection of a meaningful observation period need to be addressed.

In his book *The Sceptical Environmentalist*, Bjørn Lomborg (2001) argues that many statistical analyses on environmental status-quo or performance have failed to provide satisfactory answers to the above mentioned concerns. Lomborg states that the failure might sometimes have been due to the fact that environmental statistics or their analyses are ideologically biased. In other instances, data sources might have been inadequate or statistical techniques flawed.

The heated and at times bitter debate about Lomborg's contribution illustrates how difficult it is in practise to overcome the practical and methodological problems connected to pollution performance analysis. The question still stands whether it may be even impossible to solve them. Nevertheless, from a more positive angle, this ongoing battle of arguments and approaches also shows that, despite all criticism, quantitative environmental analysis is a lively and interesting field for empirical research.

This study will look at air pollution as a proxy for the pollution at large. This approach is in line with a large number of empirical contributions in the environmental economics literature, for example, Lundquist (1980), Crepaz (1995), Jänicke et al. (1996; 1997), Henderson (1996), Jahn (1998), Becker and Henderson (2000), and Khanna (2000).

Data basis

Before this background, the importance of commenting the source and type of data that will be used in the following analysis is obvious. At the core of this investigation are three indicators, which aim to reflect the pollution performance of the EU economies. The indicators are based on air pollution data series, which were provided by two research centres, EMEP and the Oak Ridge National Laboratory.

EMEP, the *Co-operative Programme for Monitoring and Evaluation of Long Range Transmissions of Air Pollutants in Europe*, is an international research project under the United Nations Framework Convention on Climate Change (EMEP and CORINAIR 1999; UNECE 1999; cf. Roca et al. 2001). Its principal objective is to compile reliable and internationally standardised data series on a number of air pollutants. For our purposes, this data source is especially valuable, since the first international convention on long range air pollution was adopted in Geneva in 1979 –at a time when some European countries did not even have designated environmental ministries. Therefore, the EMEP database provides a valuable insight into the development of environmental performance, as some data series provide continuous information from 1980 onwards.

The *Carbon Dioxide Information Analysis Centre* (CDIAC) of the U.S. Oak Ridge National Laboratory offers an even more extensive time series. Its database also contains estimates of historical carbon dioxide emission data. Some national data sets reach back as far as 1751. However, for the purpose of the present investigation, it is sufficient to utilize emission data reaching back to 1980.

This investigation will draw on EMEP and CDIAC data regarding anthropogenic emissions at national level for 15 member states of the European Union –that is, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom– over the period from 1980 to 1999.

Analytical framework

One fundamental characteristic about the research approach taken in this study is that it deals with pollution performance indicators, which are computed *within a relative system*. Put differently, the indicators that this study is about to develop are designed to compare national pollution levels within the framework of all countries in the data set. Hence, the pollution of each EU member state is compared to the other EU nations.

A second basic feature of the subsequent pollution performance indicators is that they are computed over a period of several years. Hence, one can compare the pollution intensity within the relative system between several points in time. The development of the indicators may therefore describe relative changes in a nation's pollution performance over the observation period.

Third, one should note that the indicators are composed from up to seven sub-indicators, each of which represents a particular type of anthropogenic air pollutant: ammonia (NH_3), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), non-methane volatile organic compounds (NMVOC), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2).

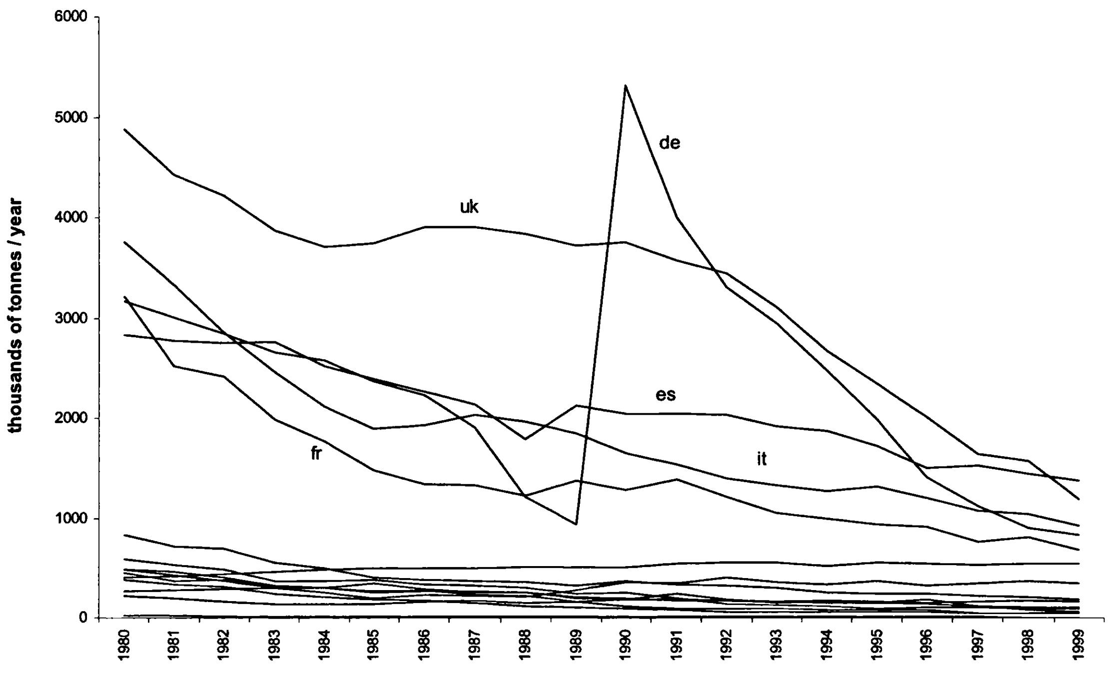
The pollution performance indicators will incorporate some or all of these sub-indicators. Each sub-indicator contributes to the final pollution performance indicator at equal weight. Note however that in some cases, indicators will be composed of less than all seven sub-indicators. This is due to data constraints.

The principle that governs the transformation of the raw pollution data into the sub-indicators applies equally to all pollutants. For the sake of clarity, the following section will focus on sulphur emissions as an example.

Figure 20 captures the development of national sulphur emissions in the 15 EU member states from 1980 to 1999 in absolute values. The data in this chart is not normalised; as a result, the information it provides cannot be used as a basis for cross-country comparisons. However, several initial observations are readily apparent. Overall, the amount of sulphur emissions in the EU has declined over the observation period. This reduction was especially pointed in Germany and the United Kingdom.[6] After 1989, the widespread rapid degradation of the East German industrial landscape as well as the proliferation of other types of domestic heating caused a swift decrease in sulphur emissions.

[6] There appears to be a striking rise of sulphur emissions in Germany between 1989 and 1990. However, this increase was probably a direct result of the German reunification. The German data series refers to West Germany until 1989 and to reunited Germany from 1990 onwards.

Figure 20 Anthropogenic sulphur (SO_2) emissions in EU member states



Data source: EMEP (2001)

In order to compare pollution values across the countries in the sample, the 'raw' pollution data will be normalised, i.e., the analysis will account for the size of the country or its economy.

There is a range of potential normalising factors, among them territory, population or economic size. From a geographic point of view, territorial size may be the first and most intuitive choice of normalising factor. However, with regard to the statistical question at hand, this normalising method appears less appropriate than the latter factors. By definition, anthropogenic, i.e. man-made, pollution is fundamentally linked to human presence and its economic activity. By contrast, territorial size is not dynamically linked to population or economic presence.

In the European Union at large, as well as within its member states, population and economic activity are not equally distributed. Consequently, in large countries with a relatively low population and economic density like Sweden, the amount of pollution per area unit would be downward biased. Inversely, in countries with relatively high population and economic density figures, such as the Netherlands, pollution per area values would be upward biased.

For this reason, pollution per capita values seem to be the appropriate starting point for an investigation into pollution performance. It will be used as an example in the following explanation on the methodological background of the indexes. Sections 3.2.1.2, 3.2.1.3, and 3.2.1.4 will develop these indexes in detail.

Following this, the normalised value of a country's pollution $N\left(AP_{it}^{j}\right)$ could be calculated as follows:

(3.1.1) $$N\left(AP_{it}^{j}\right) = \frac{AP_{it}^{j}}{population_{it}}$$

where i indexes the country, t the year and j the pollutant.

In this context, AP_{it}^{j} stands for the amount of air pollution with regard to country i, year t and pollutant j. The result of this operation yields the national average value of pollutant j per capita. In other words, this normalisation function computes the average annual pollution load, expressed for instance in grams of sulphur emissions per capita.

Table 2 Anthropogenic SO_2 emissions per capita

Anthropogenic SO_2 emissions (g / cap.)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	0.084	0.072	0.070	0.057	0.051	0.040	0.038	0.037	0.036	0.033	0.037	0.033	0.032	0.029	0.025	0.024	0.024	0.022	0.021	0.018
dk	0.088	0.072	0.074	0.063	0.060	0.067	0.057	0.050	0.050	0.039	0.036	0.047	0.036	0.030	0.030	0.028	0.034	0.021	0.015	0.011
de	0.051	0.049	0.046	0.043	0.042	0.039	0.036	0.031	0.020	0.015	0.067	0.050	0.041	0.036	0.030	0.024	0.017	0.014	0.011	0.010
gr	0.041	0.043	0.045	0.047	0.048	0.050	0.050	0.050	0.050	0.050	0.050	0.054	0.054	0.053	0.050	0.053	0.052	0.051	0.051	0.051
es	0.076	0.073	0.072	0.073	0.066	0.062	0.059	0.055	0.046	0.055	0.053	0.053	0.052	0.049	0.048	0.044	0.038	0.039	0.037	0.035
fr	0.060	0.047	0.044	0.036	0.032	0.027	0.024	0.024	0.022	0.024	0.023	0.024	0.021	0.018	0.017	0.016	0.016	0.013	0.014	0.012
ie	0.065	0.056	0.045	0.041	0.040	0.040	0.046	0.049	0.043	0.046	0.053	0.051	0.048	0.045	0.049	0.045	0.040	0.045	0.047	0.042
it	0.067	0.059	0.050	0.043	0.037	0.033	0.034	0.035	0.034	0.032	0.029	0.027	0.024	0.023	0.022	0.023	0.021	0.018	0.018	0.016
lu	0.066	0.057	0.047	0.038	0.041	0.044	0.043	0.042	0.041	0.040	0.039	0.039	0.038	0.038	0.032	0.022	0.019	0.014	0.009	0.009
nl	0.035	0.033	0.028	0.022	0.021	0.018	0.018	0.018	0.017	0.014	0.014	0.011	0.011	0.011	0.009	0.010	0.009	0.008	0.007	0.006
at	0.051	0.044	0.042	0.031	0.028	0.025	0.023	0.020	0.015	0.013	0.012	0.011	0.008	0.008	0.007	0.007	0.007	0.006	0.006	0.005
pt	0.027	0.028	0.029	0.031	0.025	0.020	0.023	0.022	0.020	0.028	0.036	0.035	0.041	0.036	0.034	0.037	0.033	0.034	0.038	0.035
fi	0.122	0.111	0.100	0.077	0.075	0.078	0.067	0.067	0.061	0.049	0.052	0.039	0.028	0.024	0.022	0.019	0.020	0.019	0.017	0.017
se	0.059	0.052	0.045	0.037	0.036	0.032	0.032	0.027	0.027	0.019	0.014	0.011	0.010	0.010	0.009	0.009	0.009	0.006	0.006	0.007
uk	0.087	0.079	0.075	0.069	0.066	0.066	0.069	0.069	0.067	0.065	0.065	0.062	0.059	0.053	0.046	0.040	0.034	0.028	0.026	0.020
AVG	**0.065**	**0.058**	**0.054**	**0.047**	**0.045**	**0.043**	**0.041**	**0.040**	**0.037**	**0.035**	**0.039**	**0.036**	**0.034**	**0.031**	**0.029**	**0.027**	**0.025**	**0.022**	**0.021**	**0.020**
COV	**0.09**	**0.09**	**0.09**	**0.08**	**0.09**	**0.11**	**0.10**	**0.10**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.12**	**0.12**	**0.13**	**0.13**	**0.15**	**0.16**	**0.16**

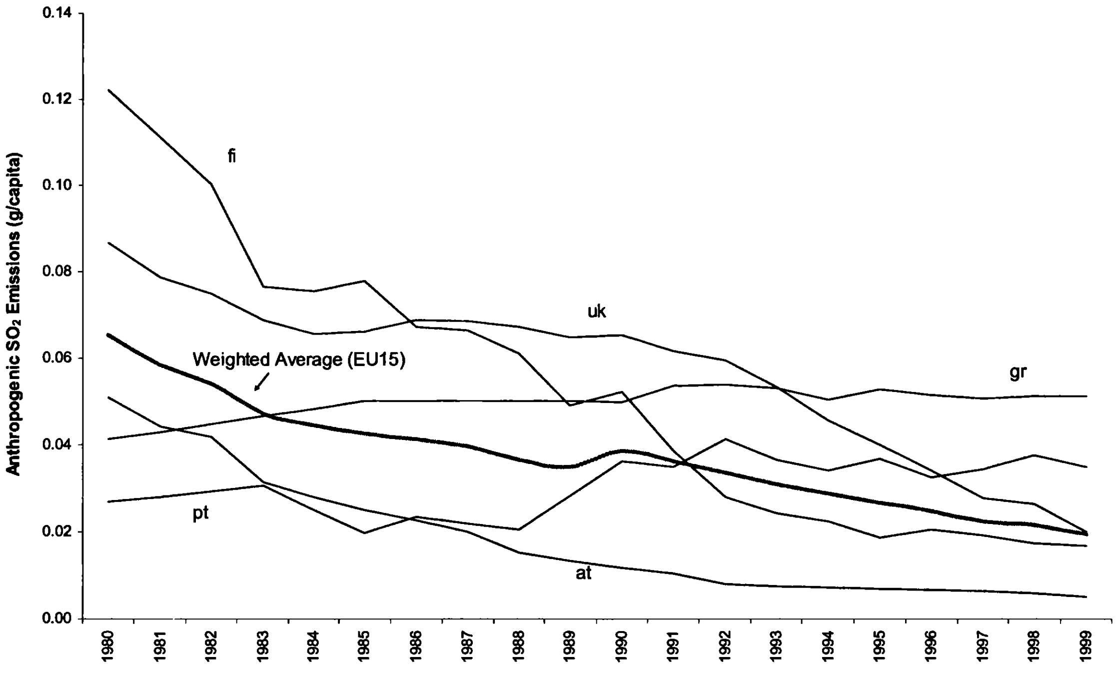
Note: AVG Weighted average (weights according to the ratio national vs. total population)
COV Coefficient of variation

Emission data (except CO_2) from EMEP (2002, es/gr/pt: 2000)
CO_2 emission data from CDIAC (2002)
Population data from Eurostat (2001)

Table 2 shows the empirical results with regard to sulphur emissions; the complete results for all seven covered air pollutants can be found in the appendix as table 27.

Figure 21 illustrates to which considerable extent the average sulphur pollution load of EU countries varied. In 1980, Finland had the highest sulphur emission levels with 0.122g per capita. On the other hand, Portugal had the lowest figure with 0.027g per capita. The average value across all fifteen EU member states, which was composed from national values that were weighted according to the countries' population numbers, amounted to 0.66 grams of sulphur emissions per capita per annum.

Figure 21 ***Anthropogenic sulphur emissions per capita, selected EU member states***



Emission data from EMEP (2002)
Population data from Eurostat (2001)

On the first look, the above graph tells a fairly straight-forward story: over the observation period, sulphur emission levels have decreased considerably in most of the 15 states that currently constitute the European Union. The weighted average has declined to 0.035g and 0.020g per capita in 1989 and 1999 respectively. As mentioned earlier, the rise in the average sulphur pollution level in 1990 may be explained by the inclusion of Eastern Germany.

The picture also illustrates that some countries have managed to cut their sulphur emission levels more than others. Both Finland and the United Kingdom exhibit a significant reduction. Sulphur emission levels in Greece and Portugal have risen significantly over the observation period. After 1994, Greece had the highest sulphur emission level per capita in the sample.[7]

On the basis of this graph, one might be tempted to conclude that a downward harmonisation of sulphur emission levels took place across the EU15 countries. This would correspond to the observations that the weighted average has decreased over the observation period and that the differences between the highest and the lowest sulphur emission figures per capita have also decreased in absolute terms.

However, such an assessment would tell only half the story. Since the average is changing over the observation period, the development regarding the differences between the highest and the lowest sulphur emission figures must be assessed in relative terms. One way to do this is by calculating the so-called coefficient of variation (COV).

The COV is a statistical tool to compare the variability of data measured across the observed years (Neumayer 2001). It is computed for a certain year t as follows:

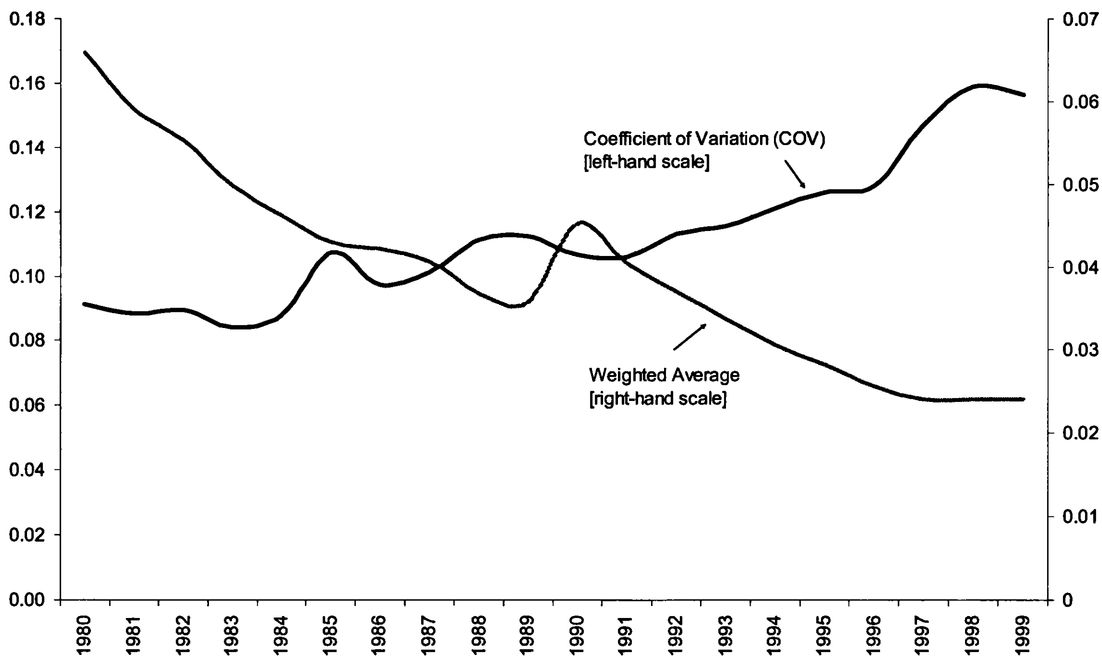
$$(3.1.2) \qquad COV_t = \frac{\frac{1}{N}\sqrt{\sum_{i=1}^{N}(x_{it} - \overline{x}_t)^2}}{\overline{x}_t}$$

[7] The reasons behind this observed change in pollution load may differ from country to country; possible explanations could include a shift to cleaner technologies, a shift in industrial structure, or the expansion or contraction of economies. Although this would be interesting background information, highlighting the individual factors for each country in the sample would exceed the scope of this thesis.

where N is the number of countries (in this case, the 15 EU member states), x_i is the sulphur emission load per capita with regard to country i at time t, and $\bar{x}_t$ is the weighted average at time t.

Figure 22 graphically displays the results of this calculation (cf. table 2). While the weighted average is decreasing, the COV is increasing over time. This seems to indicate that the relative differences in sulphur emission between EU member states have actually increased while the overall level of sulphur emissions has decreased over the observation period.

Figure 22 Anthropogenic sulphur emissions per capita (EU15): coefficient of variation and weighted average



This observation corresponds in principle to the findings presented by Neumayer (2001). Using a different data source and a slightly different calculation method, Neumayer showed that between 1985 and 1996, sulphur emission levels in the EU have decreased in average, but diverged within the sample.

This conclusion is important because it represents the rationale behind the theoretical approach to the further development of the environmental performance indicators: Looking at the development of emission levels in absolute terms certainly reveals one specific aspect of statistical reality. Such an approach may well be best suited for analyses into the pollution performance of particular states or economies on a stand alone basis. However, if the focus is on the pollution performance within a set of countries over time, the method of choice must be to look at the relative development of emission figures.

For this reason, this study will analyse pollution performance indicators which are computed within a relative system. With regard to the research question at hand, the pollution performance indicators need to compare the relative development of air pollutant emission levels across the EU and relate them to chemical industry performance. Thus, the fifteen European Union member states jointly represent the relative system that forms the focal point of the study. The scope of analysis is restricted to the relative differences within the system; the overall or absolute development of EU pollution levels as well as the EU pollution performance relative to other economies will not be the object of this analysis.

Note that this set-up inherently implies that the European Union constitutes a valid relative system. In other words, the study assumes that the EU member states to form a sufficiently homogeneous group of countries.

Air pollution time series

As mentioned before, the pollution performance indicators will be aggregates of up to seven sub-indicators. The sub-indicators capture the following anthropogenic air pollutants:[8]

- Methane (CH_4) is an integral component of the greenhouse effect, second only to CO_2 as a contributor to anthropogenic greenhouse gas emissions. Methane is mainly produced by anthropogenic sources, such as landfills, natural gas and petroleum systems, agricultural activities, coal mining, stationary and mobile combustion, wastewater treatment, and certain industrial processes. In the chemical industry, methane is a raw material for the manufacture of methanol, formaldehyde, nitro methane, chloroform, carbon tetrachloride, and Freon.
- Carbon monoxide (CO) is a colourless, odourless, tasteless and toxic gas produced as a by-product of combustion. Any fuel burning appliance, vehicle, tool or other device produces carbon monoxide gas. Carbon monoxide inhibits the blood's ability to carry oxygen to body tissues including vital organs such as the heart and brain.
- Carbon dioxide (CO_2) is one of the gases in our atmosphere, being uniformly distributed over the earth's surface.

[8] Information on air pollutant characteristics in this section was obtained through the several internet sources Columbia University Press (2001). The Columbia Encyclopaedia. **12 May 2002,** European Environment Agency (2002). EEA Multilingual Glossary. **12 May 2002; http://glossary.eea.eu.int/EEAGlossary,** Ontario Ministry of Environment and Energy (2002). Air Quality Ontario. Pollutants. **12 May 2002,** Shakhashiri (2002). Chemical of the week. **12 May 2002; http://scifun.chem.wisc.edu/chemweek,** U.S. Environmental Protection Agency (2002). EPA Global Warming Site: National Emissions. **12 May 2002; www.epa.gov/globalwarming/emissions/national/index.html.**.

Energy-related activities account for almost all CO_2 emissions. The dominant contributor is carbon dioxide from fossil fuel combustion. As fossil fuels are combusted, the carbon stored in them is almost entirely emitted as CO_2. The amount of carbon in fuels per unit of energy content varies significantly by fuel type. For example, coal contains the highest amount of carbon per unit of energy, while petroleum has about 25 percent less carbon than coal, and natural gas about 45 percent less.

Some CO_2 emissions are also produced as by-products of various non-energy-related activities. Such production processes include cement manufacture, lime manufacture, limestone and dolomite use, e.g. in iron and steel making, as well as soda ash manufacture and consumption. Commercially, CO_2 finds uses as a refrigerant as dry ice, in beverage carbonation, and in fire extinguishers.

- Ammonia (NH_3) is a colourless gas that is about one half as dense as air at ordinary temperatures and pressures. It has a characteristic pungent, penetrating odour. Ammonia forms a minute proportion of the atmosphere. It also takes part in many chemical reactions.

  Ammonia is prepared commercially in vast quantities. The major method of production is the so-called Haber process, in which nitrogen is combined directly with hydrogen at high temperatures and pressures in the presence of a catalyst. It is obtained as a by-product of the destructive distillation of coal.

  Ammonia solutions are used to clean, bleach, and deodorize; to etch aluminium; to saponify (hydrolyze) oils and fats; and in chemical manufacture. The ammonia sold for household use is a dilute water solution of ammonia in which ammonium hydroxide is the active cleansing agent. The major use of ammonia and its compounds is as fertilizers. Ammonia is also used in large amounts in the Ostwald process for the synthesis of nitric acid; in the Solvay process for the synthesis of sodium carbonate; in the synthesis of numerous organic compounds used as dyes, drugs, and in plastics; and in various metallurgical processes.

  Ammonia can attack the skin and eyes. The vapours are especially irritating, as prolonged exposure and inhalation cause serious injury and may be fatal.

- Non-methane volatile organic compounds (NMVOC) include such compounds as propane, butane, and ethane. They are emitted primarily from transportation, industrial processes, and non-industrial consumption of organic solvents. The main source of NMVOC is the combustion of fossil fuels.

- Nitrogen dioxide (NO_2) results from the combustion of fossil fuels, contributing to both smog and acid precipitation. NO_2 is hazardous to human health and the environment. It contributes to acid rain, which harms aquatic ecosystems (rivers, lakes and wetlands) as well as forests and crops.

  Nitrogen dioxide is a component of smog and ground level ozone primarily produced by the combustion of fossil fuels – mainly by vehicles, electricity generation and industrial processes. The health impacts of exposure to smog include impaired lung function in the short term as well as accelerated deterioration in lung function over the long term.

- Sulphur dioxide (SO_2) is a colourless gas. It can be oxidized to sulphur trioxide, which in the presence of water vapour is readily transformed to sulphuric acid mist. SO_2 can be oxidized to form acid aerosols. SO_2 is a precursor to sulphates, which are one of the main components of respirable particles in the atmosphere.

  Health effects caused by exposure to high levels of SO_2 include breathing problems, respiratory illness and cardiovascular disease. It also damages trees and crops. SO_2, along with Nitrogen Oxides, are the main precursors of acid rain. This contributes to the acidification of lakes and streams, accelerated corrosion of buildings and reduced visibility. SO_2 also causes formation of microscopic acid aerosols, which have serious health implications as well as contributing to climate change.

  An important source of SO_2 emissions are smelters and utilities. Other industrial sources include iron and steel mills, petroleum refineries, and pulp and paper mills. Small sources include residential, commercial and industrial space heating.

Besides being greenhouse gases, all seven air pollutants have in common that they are strongly linked to human economic activity. With the exception of methane and NH_3, the emission of the listed pollutants is, to varying degrees, the product of fossil fuel combustion.

Table 3 illustrates the availability of complete data sets regarding the seven air pollutants. All data sets are complete from 1990 onwards. The data series on CO_2, NO_2 and SO_2 are complete from 1980 onwards. CO_2 values for 1999 have been estimated on the basis of a linear projection.

Table 3 ***Air pollution data availability (national level)***

	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
CH_4											■	■	■	■	■	■	■	■	■	■
CO											■	■	■	■	■	■	■	■	■	■
CO_2	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□
NH_3											■	■	■	■	■	■	■	■	■	■
NMVOC											■	■	■	■	■	■	■	■	■	■
NO_3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SO_2	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

■ *Complete data set*
□ *Values projected (linear projection)*

Because the observation periods vary from pollutant to pollutant, this study will look at two types of pollution performance indicator time series: One time series will cover the period between 1990 and 1999 and comprise all seven air pollutants at equal weight. The second time series will cover an extended observation period (1980 to 1999) at the trade-off of comprising only three air pollutants (CO_2, NO_2 and SO_2) at equal weight.

3.2.1.2 Population-based Pollution Load Index (PLI)

The first indicator will be called *Pollution Load Index (PLI)*. It compares the development of national air pollution levels per capita to the development of the weighted EU average. The weight of country *i* (w_i) in year *t* is derived as a function of its population size relative to the European Union as a whole:

$$(3.2.1) \qquad w_{it} = \frac{population_{it}}{\sum_{k=be}^{uk} population_{kt}} \qquad \text{with} \quad k = \text{be, dk, \ldots, uk}$$

The overall weighted average with regard to pollutant *j*, $W(EU15)_t^j$, is composed as follows:

$$(3.2.2) \qquad W(EU15)_t^j = \sum_{k=be}^{uk} AP_{kt}^j \cdot w_{kt} \qquad \text{where AP stands for air pollution}$$

To avoid distorted results, the weighted average will exclude country *i* when analysing its pollution performance relative to the average:

$$(3.2.3) \qquad W(EU15 - i)_t^j = \sum_{k=be}^{uk} AP_{kt}^j \cdot w_{kt} \qquad \text{with} \quad k \neq i$$

The Pollution Load Index of country *i* with regard to pollutant *j* (PLI_{it}^j) is thus constructed as follows:

$$(3.2.4) \qquad PLI_{it}^j \quad = \quad \{[N(AP_{it}^j)/W(EU15 - i_t)] \cdot 100\} - 100$$

or,

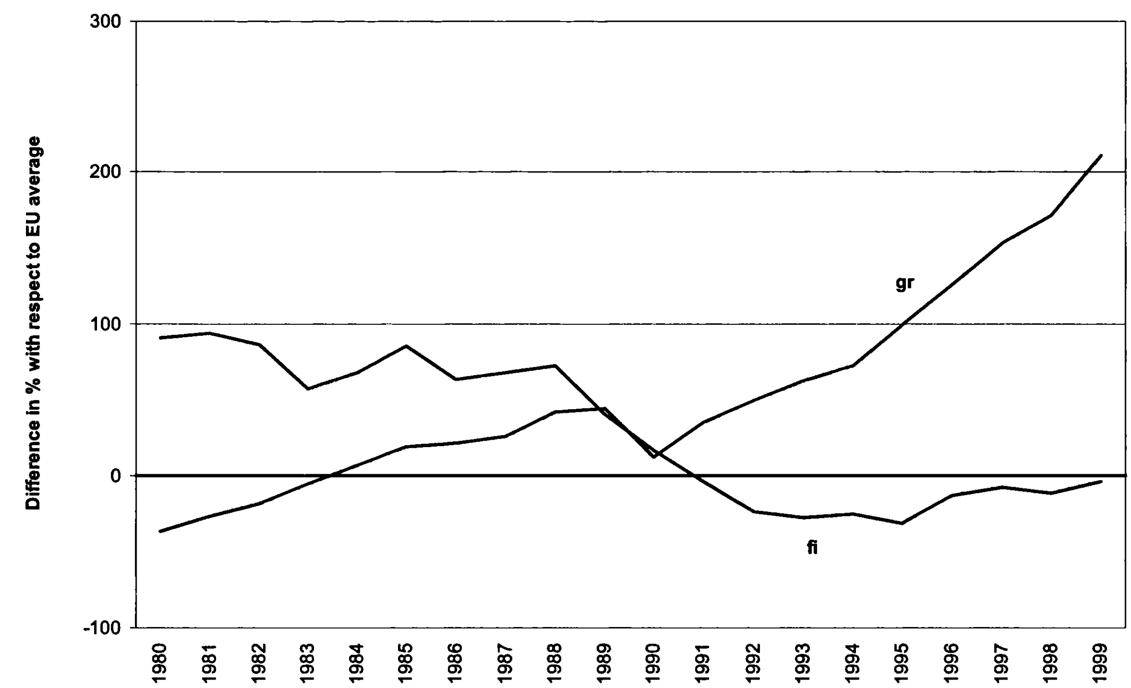
$$= \quad \left\{ \left[\frac{AP_{it}^{j}}{population_{it}} \Big/ \sum_{k=be}^{uk} AP_{kt}^{j} \cdot w_{kt} \right] \cdot 100 \right\} - 100$$

with $\quad k$ „ i

where N(AP) stands for normalised per capita air pollution.

In plain words, this operation compares the national air pollution performance per capita to the weighted EU average. The *PLI* therefore stands for the difference of national air pollution levels relative to the EU average in percent.

Figure 23 Pollution load index (SO_2 emissions): Finland and Greece



Emission data from EMEP (2002)
Population data from Eurostat (2001)

Table 29 in the appendix reports the outcome of this calculation comprehensively, both with regard to sulphur emissions, as well as with regard to the other air pollutants. The following graph also illustrates the outcome of this operation. As in the previous section, sulphur emission figures serve as examples (cf. figure 21).

As the graph illustrates, the *PLI* projects national pollution load levels onto a scale that ranges from $[-100, +\infty)$. On this scale, the value -100 would indicate zero emissions. Index value 0 would indicate that national pollution load levels were equal to the EU average, whereas positive *PLI* values point at national pollution load levels being higher than the average.

Looking at the development of the PLI values regarding the sulphur emissions of Finland and Greece, the very different sulphur pollution performance of the two countries becomes apparent. Finland has managed to reduce its sulphur pollution load from an index value that was roughly twice the EU average in the first years of the observation period to below-average values from 1991 onwards.[9]

Inversely, Greece's sulphur pollution load indicator has increased almost steadily, with the exception of the years 1989/1990. Note that this break may well be explained by the external shock of German reunification due to which the East German states were incorporated into German sulphur emission figures from 1990 onwards. Since Germany has the biggest weight in the weighted EU average, this had a significant impact on the average from 1990 onwards (cf. figure 22). Given that the indicator is constructed in relation to the EU average, that external shock introduces a break into the indicator time series.

[9] Cf. footnote 7 on page 147.

3.2.1.3 GDP-based General Pollution Intensity (GPI)

As mentioned earlier, population is not the only feasible normalising factor for national air pollution. Hence, the second pollution performance indicator will be GDP-based. Normalising a country's pollution with its economic size, expressed in GDP, yields how much pollution per unit of GDP occurs. In other words, this method reveals how much pollution an economy produces in the process of generating a unit of GDP, for instance a million Euro worth of GDP. The basic idea of the indicator is comparable to the approach of Zaim and Taskim (2000).

The *General Pollution Intensity (GPI)* index builds on this idea. Methodically, the *GPI* is constructed much in the same way as the first indicator. The main difference is that economic size, as expressed by GDP_{it}, replaces population both in the normalising as well as in the weighting function:

(3.3.1) $$GPI_{it}^{j} = \left\{ \left[\frac{AP_{it}^{j}}{GDP_{it}} \Big/ \sum_{k=be}^{uk} AP_{kt}^{j} \cdot w_{kt} \right] \cdot 100 \right\} - 100$$

with $$w_{it} = \frac{GDP_{it}}{\sum_{k=be}^{uk} GDP_{kt}}$$

and k „ i

The following table 4 displies the results of this calculation for sulphur emissions. The complete results for all pollutants can be found as table 30 in the appendix.

Table 4 *Anthropogenic SO_2 emissions / GDP*

Anthropogenic SO_2 emissions / GDP (tonnes / million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	9.60	8.06	7.91	6.13	5.07	3.75	3.27	2.98	2.71	2.29	2.42	2.05	1.83	1.61	1.28	1.16	1.12	1.01	0.93	0.79
dk	9.71	7.43	6.92	5.31	4.60	4.68	3.63	3.03	2.89	2.16	1.87	2.39	1.77	1.38	1.31	1.14	1.31	0.78	0.52	0.36
de	5.41	4.91	4.24	3.61	3.27	2.87	2.45	1.97	1.20	0.87	4.46	2.84	2.16	1.80	1.43	1.09	0.77	0.61	0.48	0.43
gr	11.07	10.22	9.11	9.62	9.27	9.63	10.54	10.54	9.21	8.31	7.69	7.53	7.22	6.96	6.26	6.15	5.52	4.99	4.98	4.57
es	18.64	16.79	15.07	15.75	12.59	10.99	9.43	8.24	6.00	6.02	5.19	4.71	4.50	4.61	4.55	3.94	3.21	3.20	2.89	2.59
fr	6.68	4.80	4.28	3.36	2.80	2.15	1.81	1.73	1.50	1.58	1.36	1.44	1.20	1.00	0.89	0.80	0.76	0.63	0.63	0.51
ie	16.67	12.22	8.75	7.47	6.98	6.33	6.79	7.12	5.79	5.60	5.84	5.33	4.74	4.38	4.35	3.69	3.01	2.91	2.87	2.30
it	11.57	9.16	7.00	5.30	4.07	3.42	3.16	3.11	2.79	2.37	1.94	1.68	1.51	1.61	1.51	1.61	1.28	1.07	1.00	0.85
lu	6.05	4.86	3.47	2.58	2.52	2.38	2.16	2.04	1.87	1.63	1.43	1.30	1.23	1.14	0.91	0.59	0.51	0.38	0.23	0.21
nl	3.97	3.61	2.84	2.12	1.87	1.52	1.45	1.40	1.29	0.98	0.91	0.74	0.70	0.62	0.52	0.48	0.43	0.37	0.31	0.28
at	6.86	5.52	4.58	3.09	2.58	2.18	1.80	1.50	1.08	0.89	0.73	0.61	0.44	0.39	0.35	0.32	0.30	0.28	0.25	0.21
pt	13.20	11.66	11.52	12.20	9.70	6.79	7.09	6.17	5.02	5.90	6.68	5.51	5.62	5.05	4.59	4.58	3.83	3.86	3.97	3.42
fi	16.06	12.06	9.56	6.92	5.84	5.52	4.74	4.39	3.50	2.42	2.52	2.05	1.79	1.79	1.44	1.03	1.10	0.96	0.83	0.76
se	5.47	4.23	3.69	2.99	2.48	2.05	2.05	1.66	1.48	0.94	0.68	0.51	0.48	0.57	0.51	0.47	0.44	0.26	0.25	0.31
uk	12.62	9.60	8.47	7.45	6.72	6.19	6.83	6.53	5.60	5.02	4.99	4.43	4.28	3.88	3.12	2.79	2.21	1.44	1.29	0.95
AVG	**10.24**	**8.34**	**7.16**	**6.26**	**5.36**	**4.70**	**4.48**	**4.16**	**3.46**	**3.13**	**3.25**	**2.87**	**2.63**	**2.45**	**2.20**	**1.99**	**1.72**	**1.52**	**1.43**	**1.24**
COV	**0.11**	**0.11**	**0.12**	**0.15**	**0.15**	**0.15**	**0.16**	**0.17**	**0.17**	**0.19**	**0.18**	**0.18**	**0.20**	**0.20**	**0.21**	**0.23**	**0.22**	**0.24**	**0.26**	**0.27**

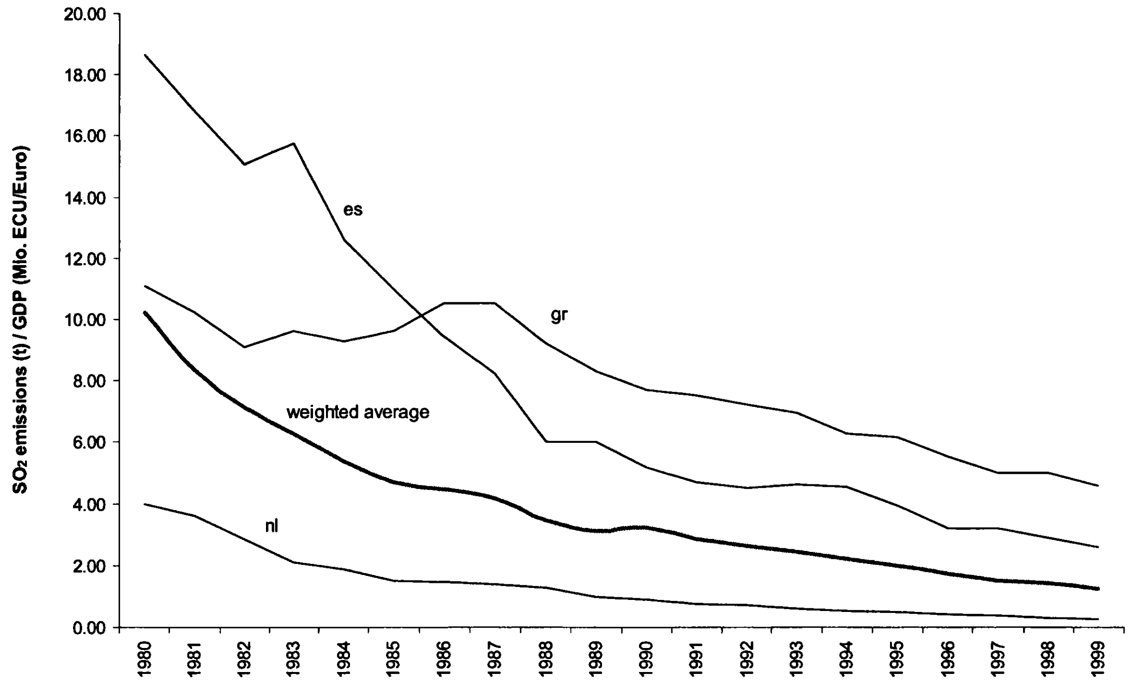
Note: **AVG** **Weighted average (weights according to the ratio national vs. total GDP)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt 2000)
CO_2 emission data from CDIAC (2002)
GDP data from Eurostat (2001)

Figure 24 graphically displays selected results of the first calculation step, the normalising operation. The average has been constructed by weighting the 15 EU member states according to their economic size (GDP), calculated on an annual basis.

The figures reveal that Spain and Greece generated relatively more sulphur emissions ("used up more clean air") to produce goods and services than other EU economies had to. In other words, the Spanish and Greek economies were more pollution intense than the EU average. Inversely, the data also show that the Netherlands were comparatively less pollution intense than other EU countries.

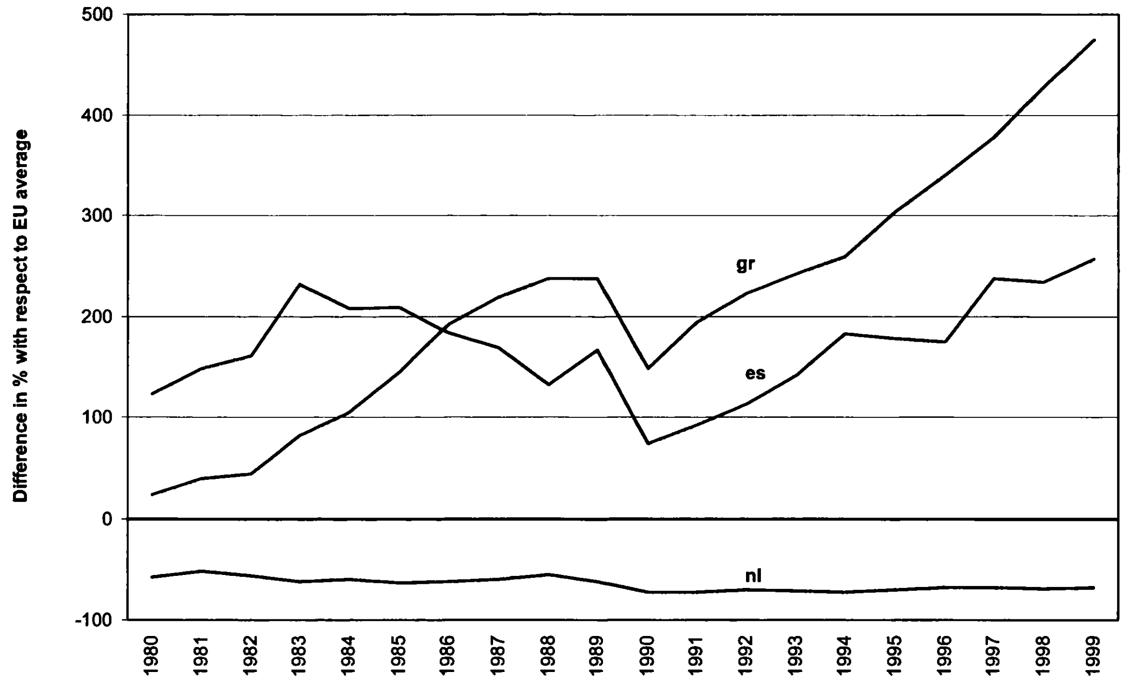
Figure 24 Anthropogenic sulphur emissions / GDP, selected EU member states



Emission data from EMEP (2002)
GDP data from Eurostat (2001)

Following the operation outlined in equation 4.3.1 above, one can transform the normalised emission figures into the GPI indicator. Figure 25 graphically represents the indicators for Greece, Spain and the Netherlands of this operation. With regard to sulphur emissions in 1980, the *GPI* was 123 in Spain and 23 in Greece. In 1999, that index was 256 in Spain and 474 in Greece. Thus, both countries' pollution intensity increased dramatically compared to the EU average over the observation period. By contrast, the general pollution intensity in the Netherlands decreased from -57 in 1980 to -68 in 1999.

Figure 25 ***General pollution intensity (SO_2 Emissions): Greece, Netherlands and Spain***



Emission data from EMEP (2002)
GDP data from Eurostat (2001)

3.2.1.4 GDP-based Manufacturing Pollution Intensity (MPI)

The third pollution performance indicator is aimed at capturing specifically the pollution performance of the manufacturing sector. Whereas the *GPI* indicator is a tool to capture inefficiency differences on the level of the *general* economy, the Manufacturing Pollution Intensity (MPI) indicator looks at the industrial pollution performance.

This approach is based on the notion that some economic sectors are more environmentally hazardous than others. In this respect, the manufacturing sector is an especially interesting case, because it produces a significant amount of pollution. One might hypothesize that manufacturing sectors are therefore especially sensitive to changes in pollution performance. The MPI indicator is constructed as follows:

(3.4.1)

$$MPI_{it}^{j} = \left\{ \left[\frac{manufacturingAP_{it}^{j}}{manufacturingGDP_{it}} \Bigg/ \sum_{k=be}^{uk} manufacturingAP_{kt}^{j} \cdot w_{kt} \right] \cdot 100 \right\} - 100$$

$$\text{with} \quad w_{it} = \frac{manufacturingGDP_{it}}{\sum_{k=be}^{uk} manufacturingGDP_{kt}}$$

$$\text{and} \quad k \neq i$$

Although the basic method of construction of this indicator remains the same as for the other two indicators, in practice, its calculation is a more difficult task. The raw data for the computation of the *MPI* has to be more specific, as the indicator puts the amount of *manufacturing* emissions ($manufacturingAP_{it}^{j}$) in relation to the *manufacturing* GDP ($manufacturingGDP_{jt}$).

The results of this operation applied to the case of sulphur emissions is recorded in table 5. The complete results for all pollutants are appended as table 31.

Table 5 Manufacturing SO_2 emissions / manufacturing GDP

SO_2 Emissions by Combustion, Manufacturing Sector (tonnes) / Manufactoring GDP (million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
be						10.73					8.46	7.76	8.45	7.86	4.03	4.14		
dk						10.57	6.46	5.18	4.29	2.89	2.85	2.88	2.41	2.05	2.02	1.49		
de								10.12	8.70	7.47	5.56	3.79	2.81	2.12	1.50	1.22		
gr						31.33	25.33	23.33	21.60	18.41	18.54	16.84	14.33	13.90	12.95	12.84		
es	53.63	51.75	39.31	33.22	25.66	22.10	20.06	18.68	18.96	15.14	14.72	13.84	12.58	13.24	12.12	10.12		
fr											3.23	3.28	2.75	2.36	2.27	1.89		
ie											10.57	8.34	7.31	7.50	7.71	5.52		
it	45.72	34.63	25.07	20.11	13.14	8.90	7.62	6.24	5.84	5.13	4.41	4.03	3.73	2.96	2.29	2.08		
lu						23.45					15.68	16.48	15.74	15.30	11.73	6.58		
nl						7.74					2.86	2.34	2.09	1.95	1.77	1.62		
at	35.88	29.31	23.64	13.16	7.88	6.27	4.98	4.00	2.80	1.84	1.78	1.16	0.77	0.63	0.50	0.58		
pt											17.14	13.38	13.52	12.01	11.15	11.39		
fi											12.06	6.12	3.40	2.23	2.17	1.42		
se											1.25	0.99	0.75	0.82	0.64	0.52		
uk	31.65	24.36	20.31	16.28	12.76	10.57	11.50	9.42	9.34	7.53	5.84	5.49	5.49	5.33	4.32	3.08		
AVG											**8.33**	**7.11**	**6.41**	**6.02**	**5.14**	**4.30**		
COV											**0.18**	**0.19**	**0.20**	**0.22**	**0.22**	**0.24**		

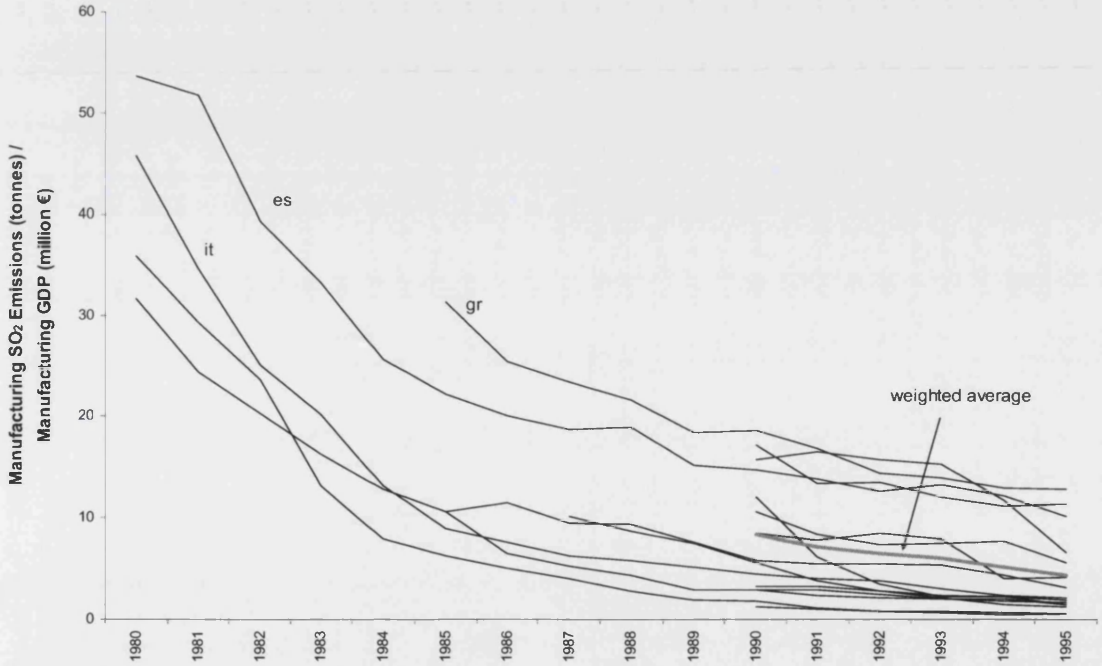
Note: AVG Weighted average (weights according to the ratio national vs. total manufactoring GDP)
COV Coefficient of variation

Emission data from EMEP (2002, es/gr/pt: 2000)
GDP data from Eurostat (2001)

Data on the GDP share of the manufactoring sector:
All countries except Ireland and Luxembourg: OECD (2000)
Ireland-- data extrapolated from Central Statistics Office, Ireland (2001)
Luxembourg-- Eurostat (2001)

As table 5 and the following graph illustrate, data scarcity restricted the compilation of a comprehensive data set to the period from 1990 to 1995. The average has been constructed by weighting the 15 EU member states according to the size of their manufacturing sector (manufacturing GDP in absolute terms), calculated on an annual basis. Since the country weights, which are necessary for the calculation of the weighted average, require complete data sets for all 15 EU member states, the weighted average could only be computed for the five years with complete data sets.

Figure 26 Manufacturing SO_2 emissions / manufacturing GDP, EU member states



Data Sources: see table 5

The variance of observations appears high, and, as in the case of the other two indicators, there appears to be a trend towards downward harmonisation across the EU in absolute values. However, as was the case concerning the normalised sulphur emission figures mentioned earlier, this impression is misleading. The rising coefficient of variation (cf. equation 4.1.2) clearly indicates that the internal difference relative to the average has increased significantly. The empirical COV in the above graph has increased from 0.18 in 1990 to 0.24 in 1995 (table 5).

3.2.1.5 Interpreting air pollution performance patterns

So far, based on the air pollution data series introduced above, this study has laid the foundation to the calculation of three different pollution performance indicators. The first indicator, called PLI (Pollution Load Indicator, cf. section 3.2.1.2) compares national air pollution levels per capita to the weighted EU average.

The second indicator, called GPI (General Pollution Intensity, cf. section 3.2.1.3) compares national air pollution levels per unit of GDP to the weighted EU average. Finally, the MPI (Manufacturing Pollution Intensity, cf. section 3.2.1.4) puts air pollution generated by the manufacturing sectors of EU member states in relation to the manufacturing GDP and compares that figure to the weighted EU average.

The following section will introduce and discuss the empirical pollution performance indicators.

Scope of the indicators

At first sight, all three indicators may appear rather similar in design and content. This may well be connected to the fact that the numerator of the three indicators is identical, i.e., an air pollution time series. Yet, each of the indicators has distinct features, which are summarised in table 6.

The table aims to illustrate that each indicator mirrors pollution performance from a different angle, and that therefore each of them has a significant analytical value.

Table 6 Advantages and disadvantages of the pollution performance indicators

Indicator	Advantages / Disadvantages
Pollution Load (air pollution per capita)	• the focus of the indicator is pollution per capita, which is the most intuitive and least economic of the three indicators • population is a relatively static denominator (with the exception of German reunification). Hence changes in the indicator are mainly due differences in pollution. • time series for all seven air pollutants from 1990 to 1999; a long-term time series from 1980 to 1999 covers three pollutants
General Pollution Intensity (air pollution per unit GDP)	• the indicator reflects pollution performance from the perspective of the general economy • GDP is a more volatile denominator; economic cycles have an impact on the indicator • time series for all seven air pollutants from 1990 to 1999; a long-term time series from 1980 to 1999 covers three pollutants
Manufacturing Pollution Intensity (air pollution per unit of manufacturing GDP)	• the indicator is specific to the manufacturing sector • reduced data availability and consistency • time series cover only two air pollutants from 1990 to 1995

Nevertheless, for consistency and transparency, the subsequent regression analysis laid out in chapter six will build on *one* primary pollution performance indicator. The overview on the indicator featured in table 6 should provide some answers to the question, which indicator could be suited best to proxy the impact of pollution performance on chemical industry performance.

Although the PLI indicator appears to be the most straight-forward index that is easiest to understand by intuition, the other two GDP-based indicators may be closer to economic reality. Since the purpose of this study is to compare the economic performance of an industrial sector to pollution performance, the indicator of choice should incorporate the concept of economic dynamism.

This reasoning would favour GPI or MPI as lead indicator for the subsequent analysis. Between the two of them, the MPI indicator would obviously be the better-suited candidate, since it is specifically designed to reflect the pollution performance of the manufacturing sector of which the chemical industry forms part.

However, there is one very important drawback to the use of the MPI as lead indicator: complete and consistent pollution data on the manufacturing sector is limited to the period of 1990 to 1995 and to two pollutants. Given that some GPI time series cover a period of twenty year from 1980 to 1999, the MPI data constraint is an important argument. Key parts of the subsequent analysis are based on quantitative methods. Therefore, the number of observations is an important practical consideration, as it determines, for example, the reliability of regression estimates.

Long-term and short-term indicators

At this point, the reader should recall once more that the three pollution performance indicators are aggregate indicators, which are composed of several sub-indicators. As an example, the 'global' GPI indicator is composed of GPI sub-indicators, each of which covers one specific pollutant. Thus, there are GPI sub-indicators for ammonia (NH_3), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), non-methane volatile organic compounds (NMVOC), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2). The 'global' pollution performance indicators are averages of those sub-indicators at equal weight.

However, some pollution time series were more comprehensive than others. As mentioned before, manufacturing pollution was complete only between 1990 and 1995. National pollution time series were complete from 1980 to 1999 for CO_2, NO_2 and SO_2. The other data sets were complete on national level from 1990 to 1999 (cf. table 3).

For this reason, two PLI and GPI indicators series may be constructed. The first set of indicators would consist of all seven sub-indicators. These PLI 7 and GPI 7 indicators account for all available pollution data. However, these comprehensive pollution performance indicators are short-term time series, since they cover only the ten years 1990 to 1999.

By contrast, if the indicators were composed only by the CO_2, NO_2 and SO_2 sub-indicators, they covered the period from 1980 to 1999. Thus, PLI 3 and GPI 3 indicator series could serve as long-term indicators.

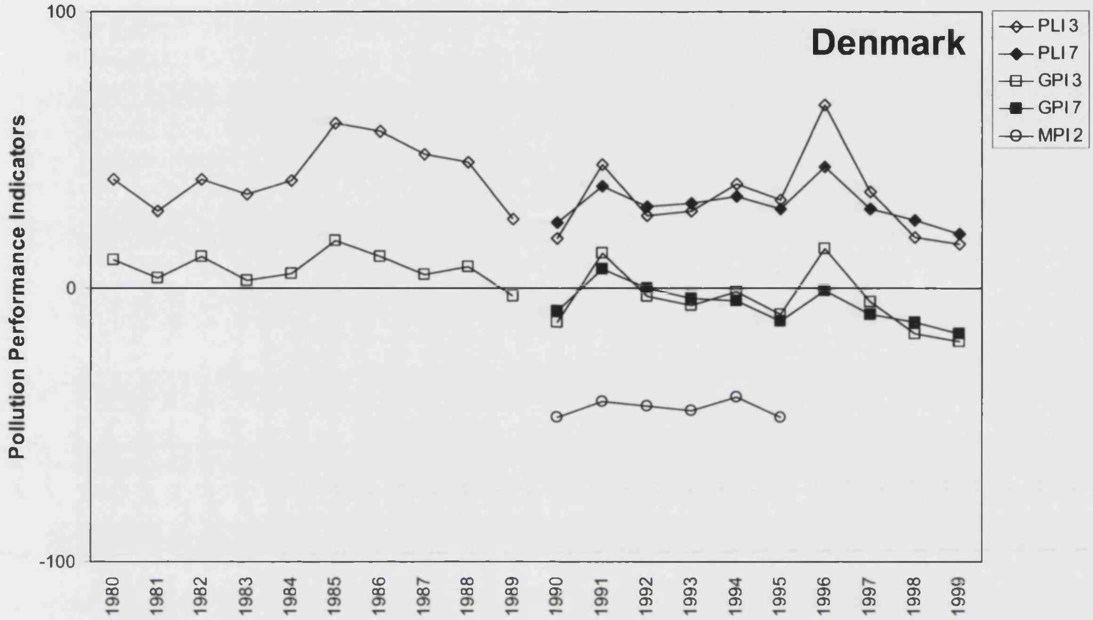
Indicator correlation

The following section will discuss the empirical pollution performance indicators by taking Denmark and Spain as examples. Tables 29 to 31 in the appendix provide all empirical pollution performance indicators for those two countries, both by pollutant as well as on an aggregate level.

Figure 27 represents the empirical results of Denmark. Because the CO_2, NO_2 and SO_2 pollution data sets allowed the compilation of a long-term time series covering the period from 1980 to 1999, there are two PLI and GPI sets. Thus, the PLI 3 and GPI 3 indicators cover the three above mentioned pollutants over a period of twenty years. Inversely, the PLI 7 and GPI 7 time series are short-term indicators, covering only ten years from 1990 to 1999 but all seven air pollutants. As mentioned before, air pollution data on the manufacturing sector was only complete over the period from 1990 to 1995 and with regard to two pollutants, SO_2 and NO_2. For this reason, the manufacturing pollution intensity is marked MPI 2.

Note that the PLI 3 and GPI 3 time series are broken between 1989 and 1990. Again, this is due to the external shock of German reunification. The indicator values up to 1989 cannot be compared to the figures thereafter, because the relative system on which the indicators are based has shifted.

Figure 27 Empirical pollution performance indicators, Denmark



There are a number of observations one may draw from the Danish example. First, the PLI and GPI long-term time series appears to be highly correlated to the short-term time series. This holds true both with regard to the absolute value of the indicators as well as with regard to their evolution over time.

Second, the three indicators also appear to be correlated with regard to their evolution over time. The correlation between PLI and GPI appears to be relatively higher than the correlation of each of these indicators with the MPI figures.

Third, there are clear and persistent differences with regard to the absolute indicator values. In the case of Denmark, the PLI indicator is considerably higher than the GPI. In other words, the pollution load per capita in Denmark is clearly above the EU average, whereas the pollution intensity of the Danish economy as a whole is more or less equal to the EU average. The pollution intensity of the Danish manufacturing sector is consistently below the EU value.

A correlation analysis of the long-term and short-term pollution performance indicators reveals the very high degree of association between the two time series in most EU member states.

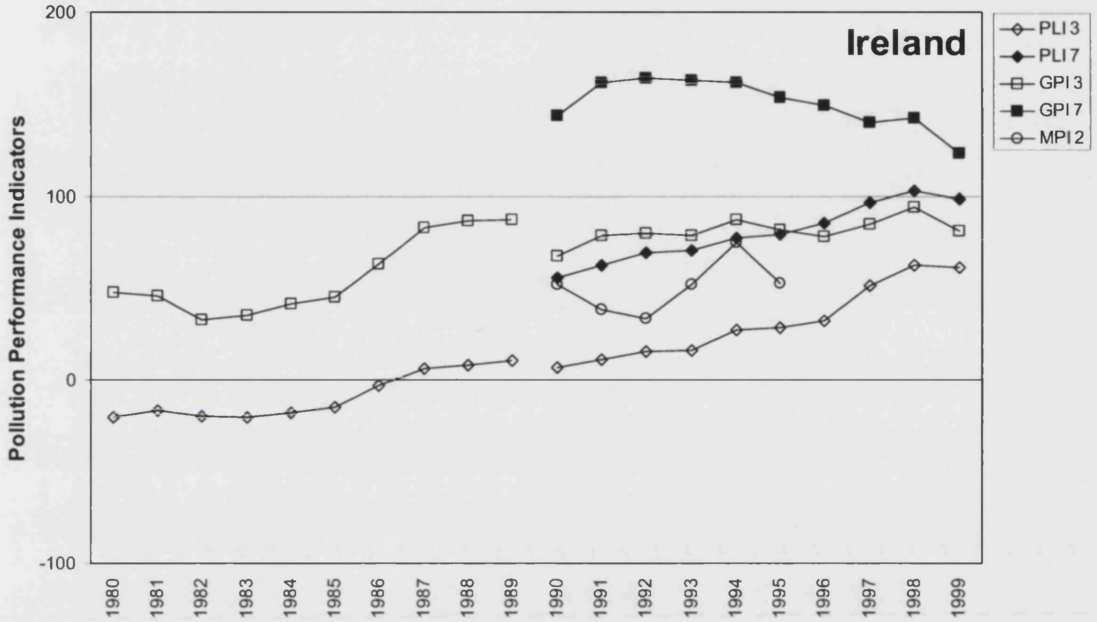
Table 7 ***Correlation coefficients between pollution performance indicators***

	PLI 3 / PLI 7	GPI 3 / GPI 7	PLI 3 / GPI 3	GPI 3 / MPI 2	PLI 3 / MPI 2
be	0.98	0.98	0.75	-0.23	0.36
dk	0.96	0.88	0.87	0.75	0.69
de	0.98	0.99	0.83	0.97	0.91
gr	1.00	1.00	0.94	0.92	0.94
es	0.99	1.00	0.74	0.98	0.94
fr	0.72	0.94	0.86	0.01	0.10
ie	0.98	-0.05	0.82	0.39	0.58
it	0.62	0.95	0.64	-0.79	-0.59
lu	0.98	0.99	0.75	0.63	0.86
nl	0.25	0.89	0.42	-0.16	-0.05
at	0.80	0.86	0.97	0.75	0.79
pt	0.99	0.99	0.97	0.99	0.93
fi	0.95	0.98	0.12	-0.64	0.83
se	0.80	0.98	0.80	-0.47	-0.20
uk	0.99	1.00	0.88	0.44	-0.08
AVG	0.87	0.89	0.76	0.30	0.47

The correlation coefficients between PLI 3 and PLI 7, GPI 3 and GPI 7, as well as between PLI 3 and GPI 3 appear to be consistently positive except in one instance. The average coefficients are well above 0.75, which seems to indicate a very high degree of correlation.

The notable exception is the correlation coefficient between GPI 3 and GPI 7 in Ireland, which is very close to nil. That observation seems to indicate an almost complete independence between the two data sets. Figure 28 illustrates how the GPI 3 and GPI 7 indicators appear to converge instead of running more or less parallel. As the correlation analysis shows, Ireland is the only country in the sample that exhibits this behaviour.

Figure 28 Empirical pollution performance indicators, Ireland



One reason for this peculiar conduct appears to lie in the development of the Irish GPI indicator concerning SO_2 emissions. Unlike the other six Irish GPI indicators, which are generally stable or decreasing between 1990 and 1999, the SO_2 pollution intensity increases significantly from 86 in 1990 to 173 in 1999. Since this SO_2 sub-indicator accounts for one third of the aggregated GPI 3 indicator but only for one seventh of the GPI 7 indicator, the GPI 3 is much more sensitive to this distinct behaviour.

The empirical GPI results indicate that this sharp increase of the SO_2 GPI indicator is not an exclusively Irish phenomenon. One can observe similar patterns with regard to Greece, Portugal and Spain. However, in contrast to Ireland, the other pollution indicators also increase in those three countries, which means that the SO_2 GPI development is more accentuated but generally in line with the other pollutants.

Lastly, the results represented in table 7 show that the average correlation coefficient between PLI 3 and MPI 2 is 0.47; the figure is 0.30 with regard to GPI 3 and MPI 2. This observation indicates that the MPI indicator is positively linked to the other two pollution performance measures, although its degree of correlation is small. This may be due to the fact that the PLI and GPI indicators are based on the same emission data aggregated on national level, whereas the MPI indicator uses a completely different and less aggregated data set.

One may draw two basic conclusions from the above discussion. First, the three pollution performance indicators are sufficiently different with regard to their scope and data basis to stand alone as individual indicators. For this reason, one part of the subsequent empirical analysis will use all three indicators to categorise EU member states according to their pollution performance. For this, the fact that the three indicators address the same issue from different angles should be rather an advantage.

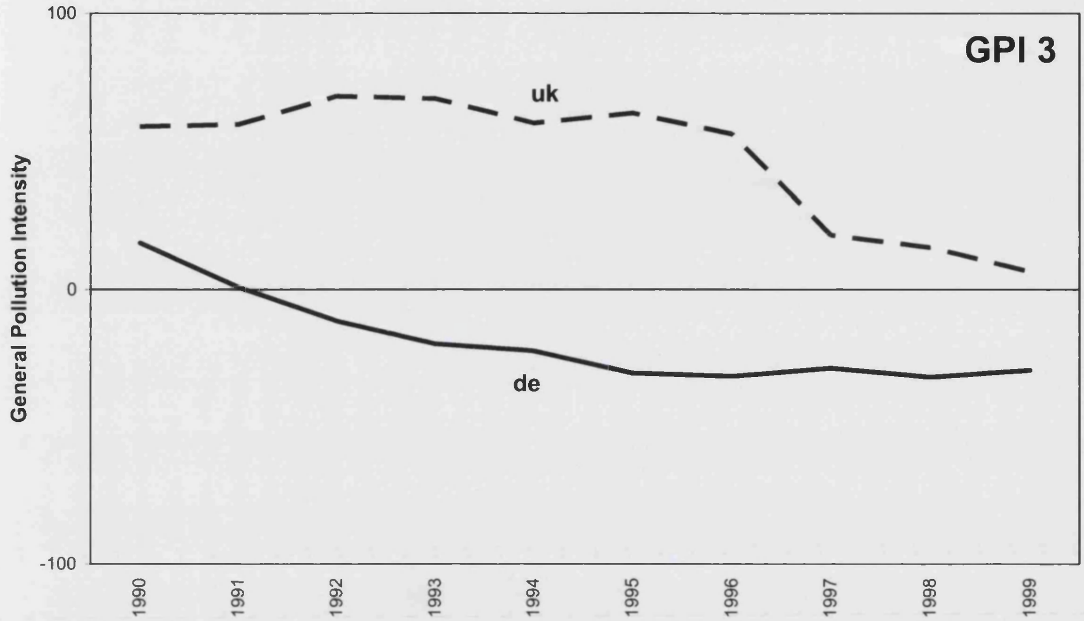
On the other hand, as the correlation analysis has shown, the indicators are clearly linked to each other. This should improve the efficiency of quantitative analyses, when one of the indicators could stand as proxy for the two others. Taking all aspects into consideration, this proxy would best be the long-term general pollution intensity (GPI 3) indicator, as it combines economic focus with the largest available pool of observations.

Indicator interpretation

Figure 29 provides an example of how pollution performance indicators develop over time: in this instance, with regard to the GPI 3 indicators in Germany and Britain. The graph illustrates the point that the interpretation of the indices can be tricky. In both countries, the GPI 3 indicator decreased over time indicating an improvement in environmental performance.

With regard to Germany, that indicator decreased by 46 points, from 17 in 1990 to -29 in 1999. In the United Kingdom, the index apparently declined at a higher rate; from 59 to 6 over the same period of time. Thus, the British pollution intensity went down by 53.

Figure 29 *GPI 3, Germany and United Kingdom, 1990 to 1999*



However, this observation does not necessarily indicate that Britain has a better pollution performance than Germany. The reason for this at first sight surprising fact is that the UK is improving its index from a considerably higher starting level. As Britain is catching up to approach the EU average, Germany appears to expand its lead over the EU average from 1992 onwards. Due to the way the pollution performance indicators are constructed, (-100) is an asymptote, because pollution values cannot be more than 100 percent less than the EU average. Thus, the closer observed indicator values get to (-100), the slower indicator values are going to continue decreasing.

For this reason, any comparison of pollution performance indicators between countries must account for both the indicator *development* over time as well as for the indicators' *overall position* relative to the EU average. The former may be achieved by looking at the trend of an index in absolute numbers as compared to the EU average, normalised to zero. In other words, the first task would be to assess whether the indicator shows a statistically significant trend over time.

A second step needs to calculate the overall position of the indicator compared to the EU average. Measuring the deviation of the index-average (taken across all years in the observation period) from zero could achieve this objective.

As a conclusion to the empirical pollution performance chapter, this section will compare how the European Union member states have presented themselves with regard to the three pollution performance indicators over the period from 1980 to 1999. The aim of this empirical study is to develop some sort of categorisation or ranking that tells which countries exhibited a generally strong pollution performance and which ones have shown a generally weak one.

In this context a 'strong pollution performance' indicates a better-than-EU-average pollution indicator development, that is, it flags countries where air pollution has gone down relative to the EU average. Inversely, 'weak pollution performance' countries would show a worse-than-average pollution performance; their pollution figures would have increased relative to the EU level.

3.2.1.6 A pollution performance 'ranking' of EU member states

At this point, the obvious question most people would ask is "so, who is polluting the most?", or "how is my country doing?" Let us have a look.

This categorisation exercise will compare the PLI, GPI and MPI indicator of the EU member states. As mentioned earlier, since the reunification of Germany in 1989/1990 introduced an external shock into the relative system on which the pollution performance indicators are based, it would be methodically unsound to compare indicator values before and after this time mark. Therefore, the analysis will only compare the pollution performance indicators after 1990.

The upside of this time restriction is that the comparative analysis can use the more comprehensive short-term indicators PLI 7 and GPI 7, as well as the MPI 2 indicator. This allows comparing national pollution performances on the broadest available range of air pollutants.

As mentioned before, a comparative analysis will need to take into account both the development as well as the relative position towards the average of the pollution performance indicators. The categorisation exercise will therefore assess the following dimensions:

- ***PLI 7 trend*** over the observation period 1990 to 1999. The trend values correspond to the coefficient of the time dummy in a regression where the dependent variable is PLI 7.

  This observation captures the relative evolution over time of the pollution load indicator compared to the EU average. An upward PLI 7 trend indicates an increase in the aggregated national pollution load, as measured in pollution per capita, has grown relative to EU average. Hence, the country's pollution performance has under-performed the EU average. Inversely, a downward PLI trend would point at stronger-than-average pollution performance.

- ***PLI 7 deviation***, written Dev (PLI 7), indicates whether the average value of the PLI indicator across the observation period is above or below the EU average, which is normalised to zero. This measure mirrors the long-term per capita pollution level of a country. If Dev(*GPI*) has a value that is larger than zero, the country has a higher per capita pollution load over the period than the EU average. The reasons for this structural difference may be of economic nature, such as the development level of a country, or due to other factors such as climate. Inversely, if Dev(*GPI*) shows a value smaller than zero, it would indicate that the country has structurally less average per capita pollution over the observation period than the EU as a whole.

- The ***GPI 7 trend*** over the observation period captures the relative pollution performance at the level of the general economy compared to the EU average. An upward GPI 7 trend would indicate that the economy's pollution intensity has increased relative to EU average. Hence, the country would have a worse pollution performance with regard to the general economy than the EU. A downward GPI 7 trend would stand for a stronger-than-average pollution performance.

- The ***GPI 7 deviation***, Dev (GPI 7), shows whether pollution intensity of a member state's economy has been, in average over the observation period, above or below the EU level. This figure reflects the overall economic structure and pollution efficiency. If Dev(GPI 7) has a value larger than zero, the economy is structurally more pollution intense than the average. In other words, that economy 'needs consume in average more clean air' than other EU economies to produce the same amount of GDP over the observation period. Inversely, lower than zero Dev(*GPI*) values would indicate that the economy is less pollution intense, and is thus 'greener' than the average.
- The ***MPI 2 trend*** focuses on the pollution intensity of a country's manufacturing sector relative to the EU average. It echoes the relative pollution performance of the relative pollution performance of industries and other production sectors. If the MPI 2 trend is upwards, the pollution intensity of the national manufacturing sector has grown relative to the EU. Therefore, the manufacturing pollution performance would be considered worse-than-average. On the other hand, a downward MPI 2 trend value would hint at a better-than-average pollution performance of the manufacturing sector.
- Lastly, the ***deviation*** of a country's ***MPI 2*** average, Dev (MPI 2), indicates whether a country's manufacturing sector is over the observation period more or less pollution intense than the EU average. If Dev (MPI 2) is shown to be above zero, the manufacturing sector is historically over the observation period more pollution intense, and therefore less efficient, than the EU average. Hence, the manufacturing sector would structurally under-perform the EU average, because it generally generates more air pollution than the other EU manufacturing sectors while producing the same value of goods. Inversely, a Dev (MPI 2) value below zero would indicate better-than-average pollution intensity structure.

Pollution performance scenarios

Before we can go on to classify the European Union member states according to their pollution performance based on the above mentioned six observations, there needs to be a definition of performance scenarios. The pollution performance trend and deviation provides information on two sorts of dimensions: the deviation reveals whether the country starts from a relatively high or low initial pollution levels, whereas the trend reveals the evolution of the pollution performance indicator. If these two dimensions are combined, there are four potential scenarios:

Table 8 ***Pollution performance scenarios***

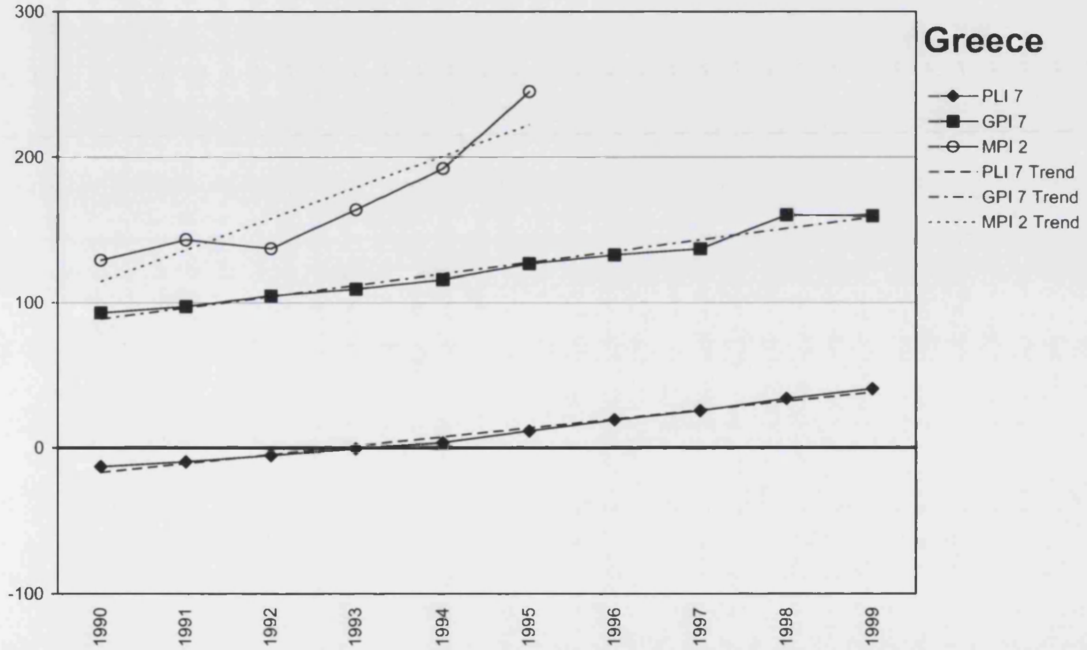
	Poor pollution performers	**Catching-up countries**	**Falling-behind countries**	**Strong pollution performers**
Deviation	High initial pollution levels	High initial pollution levels	Low initial pollution levels	Low initial pollution levels
Trend	Lack of convergence	Convergence	Convergence	Lack of convergence

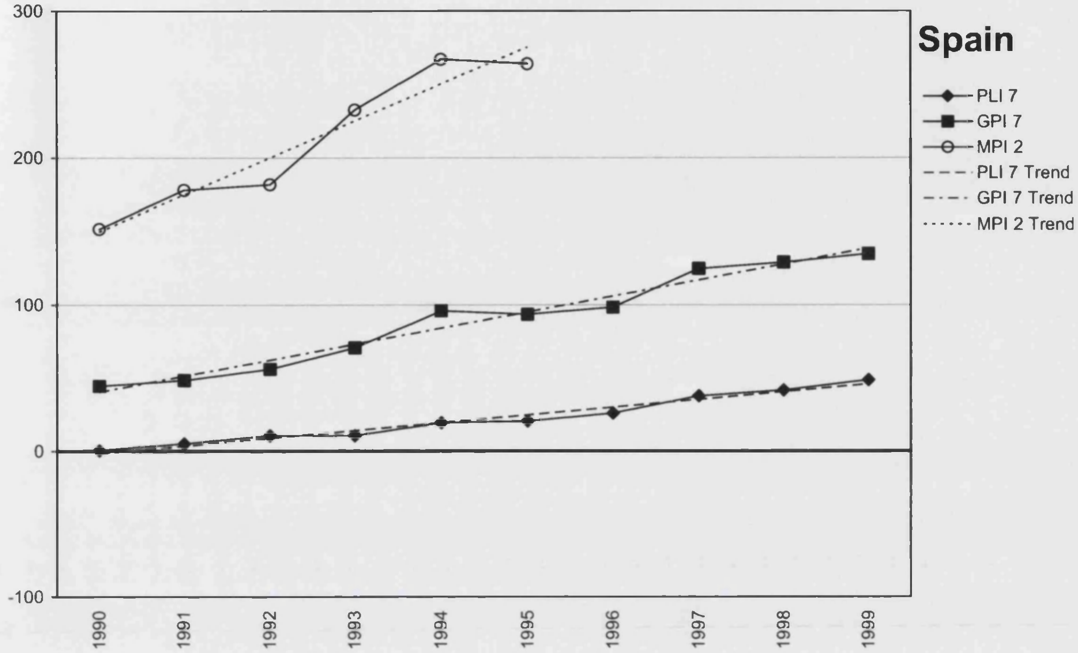
Poor pollution performers

The first country cluster consists of **Greece, Spain and Portugal**. The observed data suggests for these countries a very weak pollution performance over the observation period. The graphic representation of the pollution performance indicators in figure 30 illustrates that the country cases in this cluster possess a number of common features:

First, with regard to all countries and to all pollution performance indicators, the trend values are upward and, as noted in table 9, highly significant. In other words, the pollution performance of the countries in this group clearly deteriorated relative to the EU average over the observation period. Secondly, in all cases, the deviation of the three observed pollution performance indicators was above zero. This indicates that the said deterioration of the pollution performance captured by the upward trend values took actually place in countries that were already doing worse than EU average.

Figure 30 Pollution trends: poor pollution performers




Spain
PLI 7
GPI 7
MPI 2
PLI 7 Trend
GPI 7 Trend
MPI 2 Trend
300
200
100
0
-100
1990
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1992
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1995
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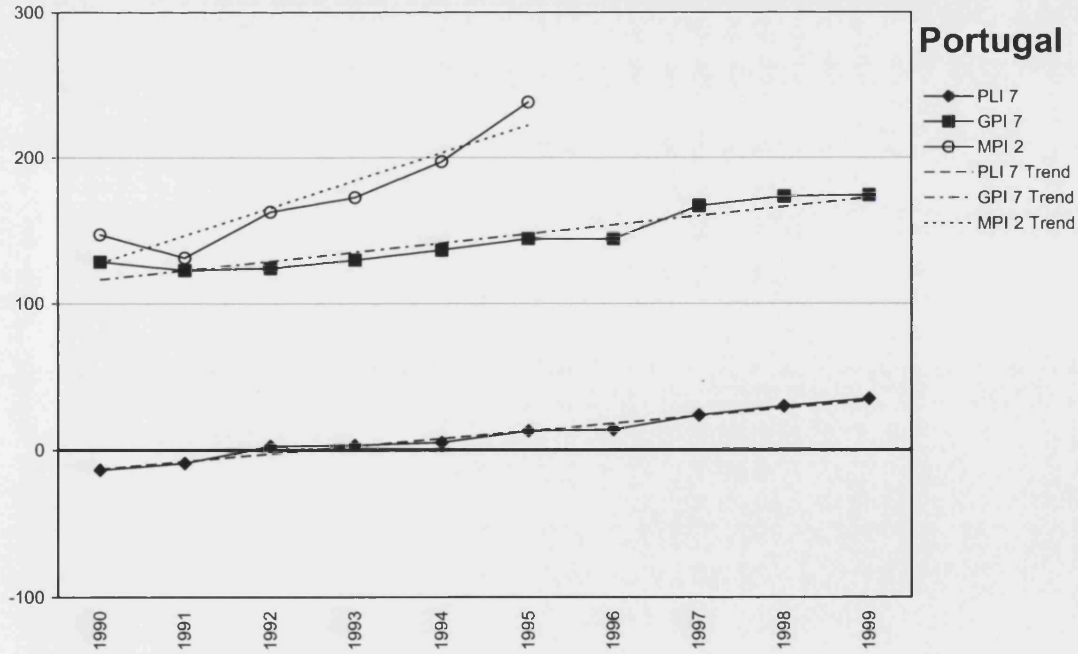
1997
1998
1999


Portugal
PLI 7
GPI 7
MPI 2
PLI 7 Trend
GPI 7 Trend
MPI 2 Trend
300
200
100
0
-100
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

Based on these observations, it appears fair to conclude that Greece, Spain and Portugal showed a poor pollution performance pattern relative to the rest of the European Union over the period from 1990 to 1999. One should note that this poor pollution performance was particularly pointed with regard to the manufacturing sector. As the trend values in table 9 reveal, the manufacturing pollution performance deteriorated much more rapidly than the other two pollution performance indicators.

Table 9 Pollution performance indicators: poor pollution performers

	Greece	Spain	Portugal
PLI 7 Trend	**+6.1****	**+5.3****	**+5.2****
Dev (PLI 7)	+11	+22	+10
Overall performance	Poor	Poor	Poor
GPI 7 Trend	**+7.8****	**+10.9****	**+6.3****
Dev (GPI 7)	+124	+90	+144
Overall performance	Poor	Poor	Poor
MPI 2 Trend	**+21.6***	**+25.2****	**+18.9****
Dev (MPI 2)	+168	+213	+175
Overall performance	Poor	Poor	Poor

* Significant at 90% level
** Significant at 99% level

Overall, the similarities between Greece, Spain and Portugal with regard to their pollution performance indicators seem remarkably strong. Besides their particularly pollution intensive manufacturing sectors, all three countries were more or less EU average with regard to per capita pollution intensity at the beginning of the 1990s. The indicators have since deteriorated at roughly the same rate, i.e. at five or six index points per year. The countries' GPI indicator also appears to follow this pattern.

In conclusion, the empirical figures seem to indicate that Greece, Spain and Portugal form a remarkably clear cut and homogenous pollution performance cluster. This could of course be due to rather obvious factors, as those Southern European countries share to some degree a comparable economic, cultural and geographic setting.

However, the empirical data indicates a much lower degree of similarity with regard to other pollution performance clusters. As the other results below will show, this holds true even to groups of countries of which one might expect similar pollution performance patterns, such as the Nordic states or the Benelux countries.

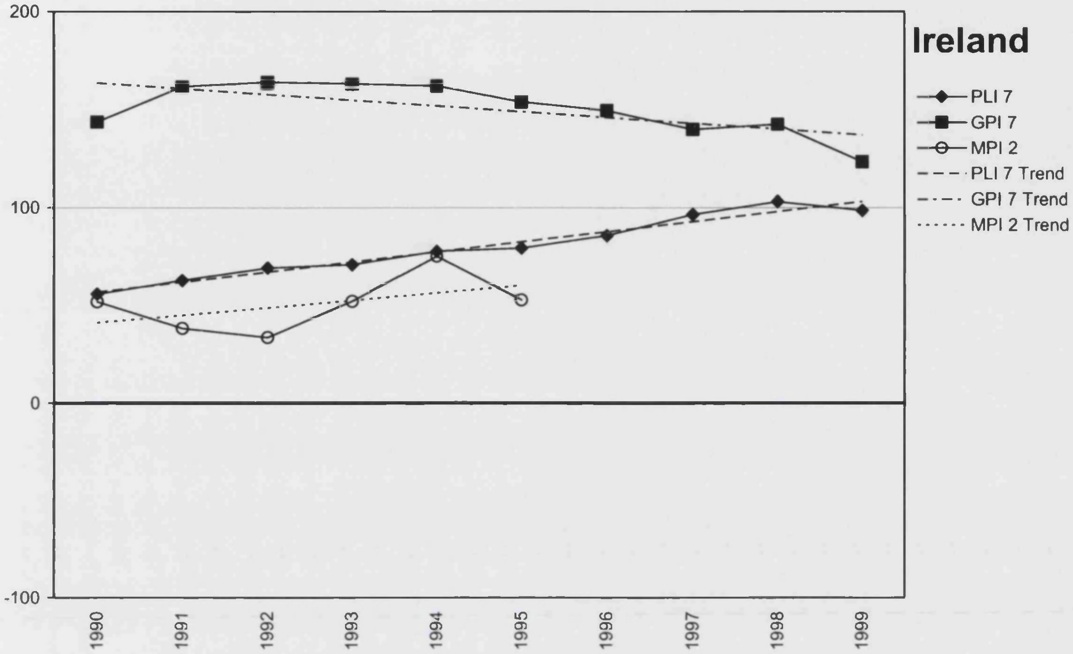
Countries that catch-up

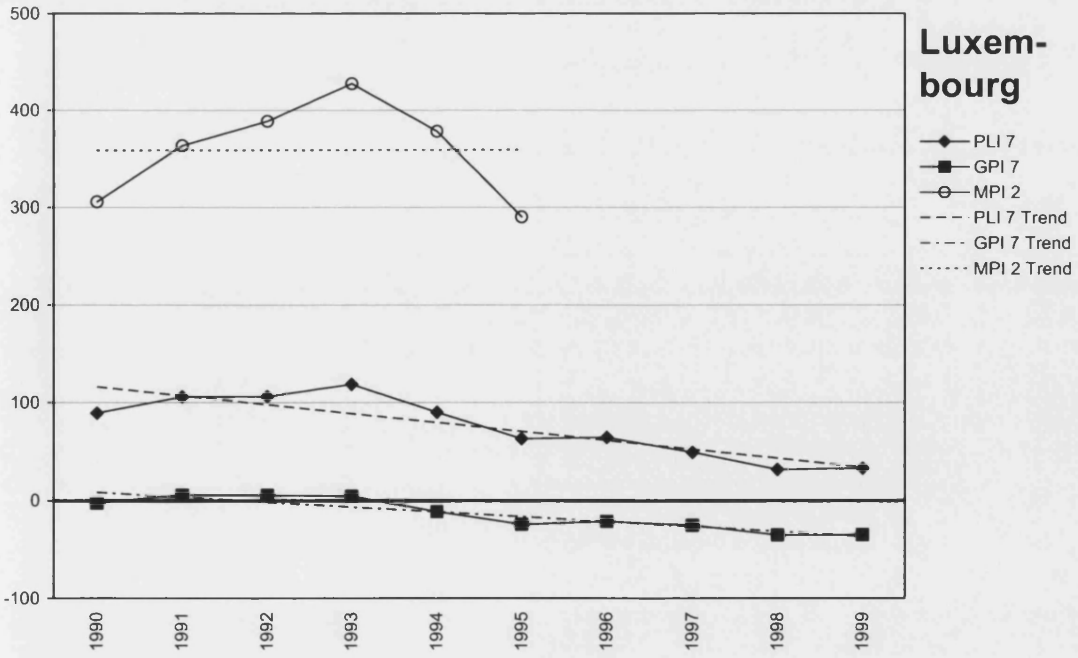
The second cluster comprises **Ireland, Luxembourg and the United Kingdom**. The pollution performance of those countries may be characterised as ‘poor but improving’. In other words, although the pollution performance of the countries in this cluster was overall below EU average, at least one of their performance indicators improved over the observation period.

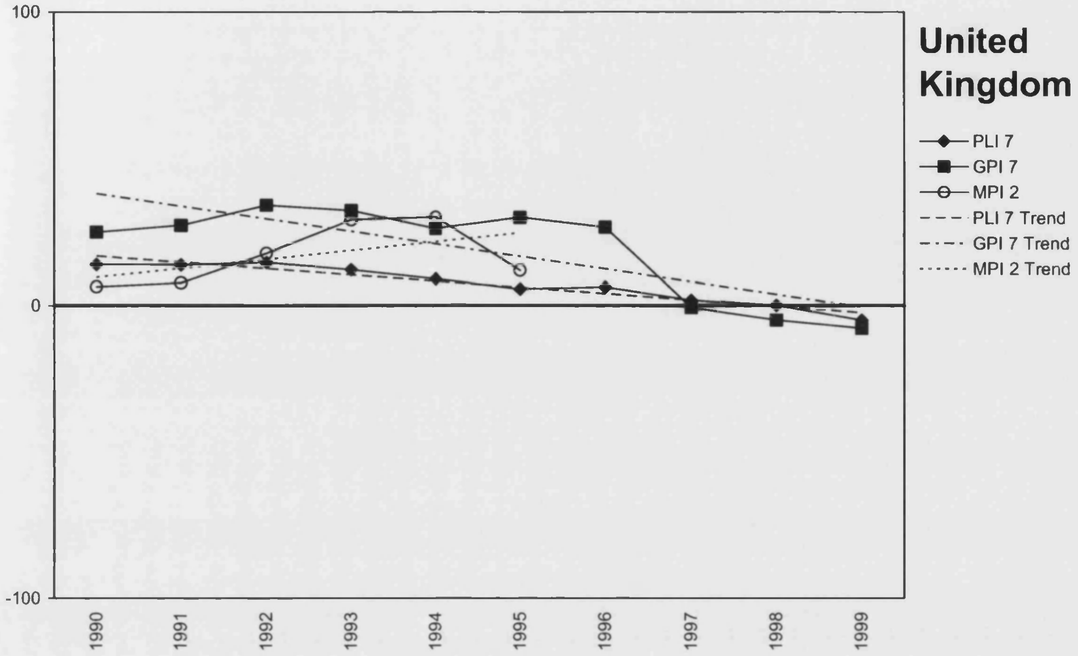
Just by looking at the graphs represented in figure 31, one probably gets the intuitive impression that this country cluster is much less homogeneous that the one presented earlier. The pollution indicators of the UK appear to lie very close to zero, which represents the EU average. In contrast, both Ireland and Luxembourg exhibit much greater pollution index deviations. There are, however, also some common trends among the three countries in this group, as table 10 illustrates.

First, the general pollution intensity (GPI 7) indicator is decreasing significantly across all three countries. In other words, their economies appear to become more pollution efficient over time.

Figure 31 Pollution trends: countries that catch-up







Second, the manufacturing pollution intensity (MPI 2) across all three countries has been less consistently above the EU average. Furthermore, the fact that all three MPI 2 trend values appear to be insignificant seems to indicate that the Irish, Luxembourgian, and British manufacturing sectors remain relatively more polluting than the EU average.

Third, the pollution load index (PLI 7) in Luxembourg and the United Kingdom decreased significantly over the observation period, whereas it appeared to increase significantly in Ireland. This seems to be a reflection of Ireland's extraordinary economic growth in the 1990s. In other words, although the pollution efficiency of the Irish economy increased, the overall pollution load actually increased due to the very high growth rates in economic activity.

Table 10 ***Pollution performance indicators: countries that catch-up***

	Ireland	**Luxembourg**	**UK**
PLI 7 Trend	**+5.2****	**-9.1****	**-2.1****
Dev (PLI 7)	+80	+75	+7
Overall performance	Poor	Catching-up	Catching-up
GPI 7 Trend	**-2.9***	**-5.0****	**-4.3****
Dev (GPI 7)	+150	-14	+19
Overall performance	Catching-up	Strong	Catching-up
MPI 2 Trend	+3.8	+0.2	+3.0
Dev (MPI 2)	+51	+359	+17
Overall performance	Poor	Poor	Poor

* Significant at 90% level
** Significant at 99% level

In conclusion, the pollution performance patterns of Ireland, Luxembourg and the United Kingdom seem to convey the overall picture of economies that are on their way towards increased pollution efficiency. This country group appears much less homogeneous than other pollution performance clusters, which may be explained by at least two reasons. First, the cluster includes Luxembourg, which may exhibit some rather freakish performance indicator behaviour, due to its small size and, in particular, due to its industrial structure. Second, this cluster also includes Ireland, which experienced a period of extraordinary economic growth over the observation period. One might suspect that, once this boom is over, Ireland's pollution performance should fall into line with the British performance pattern.

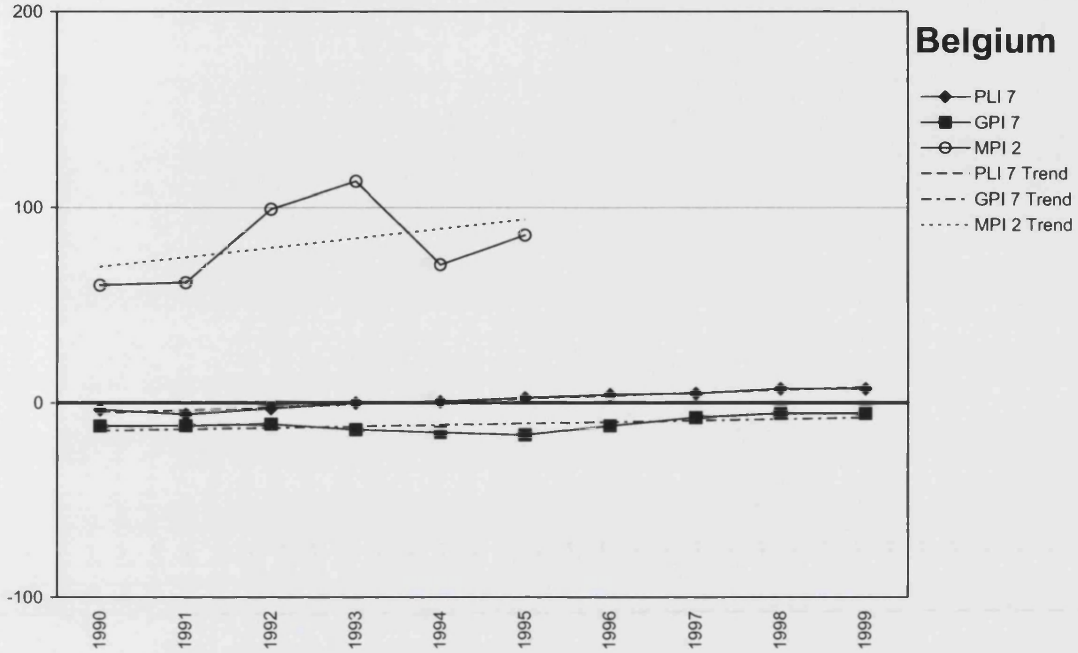
Falling-behind pollution performers

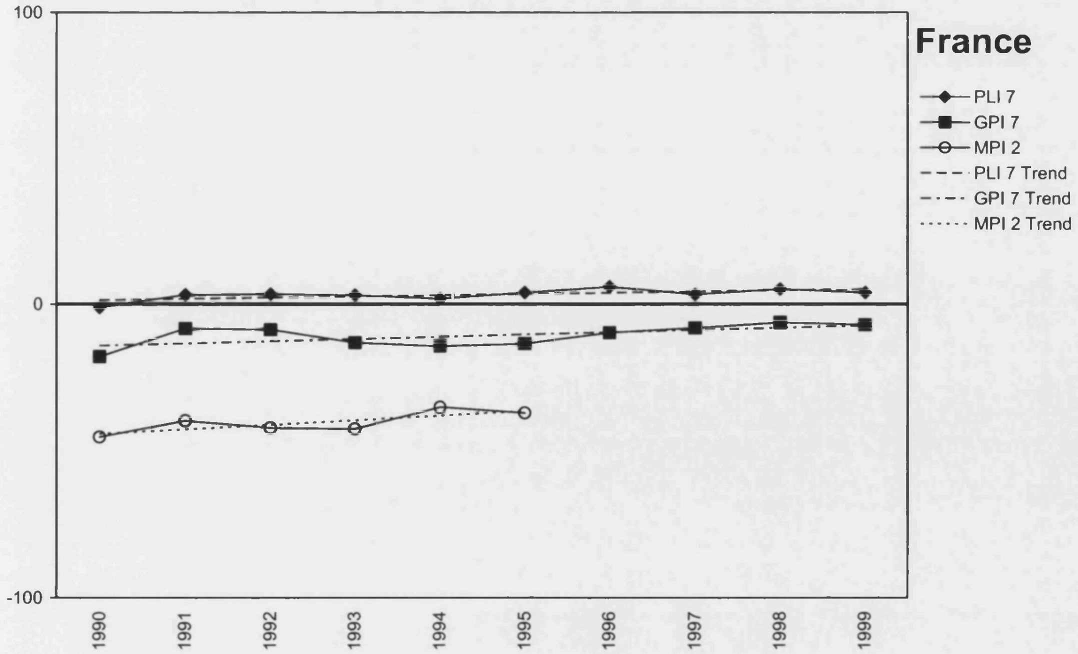
The third pollution performance cluster is made up of countries that come from a position of relatively strong pollution performance, but appear to lose their lead. There are five countries in this category: **Belgium, France, Finland, Italy, and Sweden**. Their performances are graphically represented in figure 32.

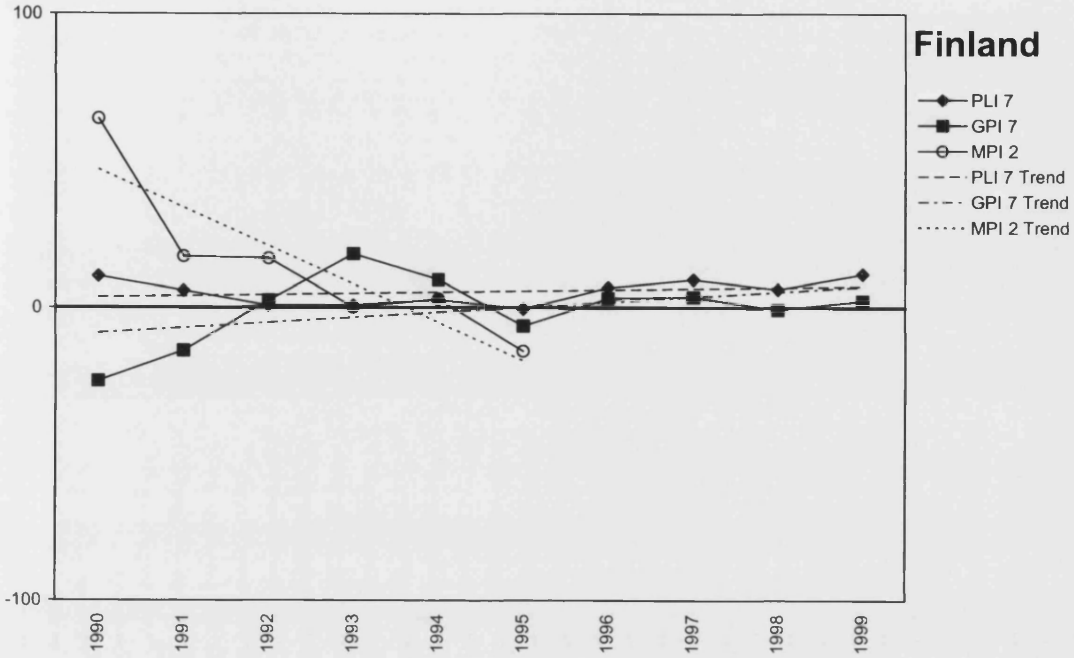
The big common denominator among those five EU member states is that all of them appear to have a general economy that was –in average over the observation period– more pollution efficient than the EU average, but shows clear signs of deterioration. In fact, as table 11 shows, the GPI 7 indicators of almost all countries in this cluster exhibit a significant upward trend, with the only exception being Finland that shows an upward trend which is below the 90% significance level.

This overall trend towards increasing pollution levels also appears to manifest itself with regard to the overall pollution load. The PLI 7 indicators of all five countries in the cluster exhibit upward trends, although this development appears to be statistically significant only with regard to Belgium and France.

Figure 32 Pollution trends: countries that fall behind






100
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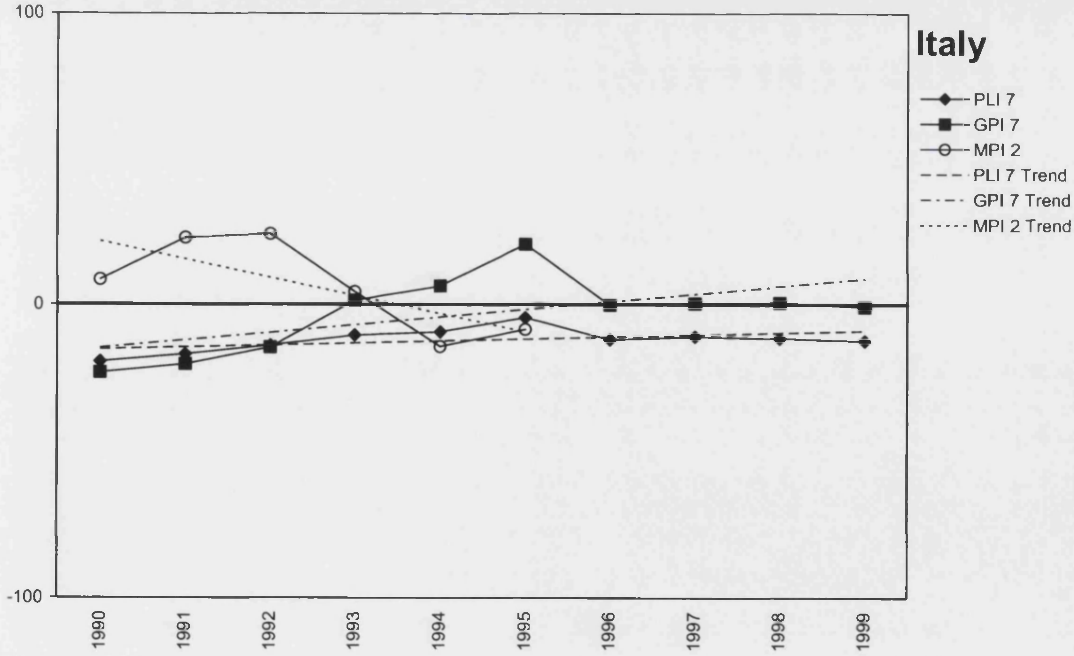
Finland
PLI 7
GPI 7
MPI 2
PLI 7 Trend
GPI 7 Trend
MPI 2 Trend


100
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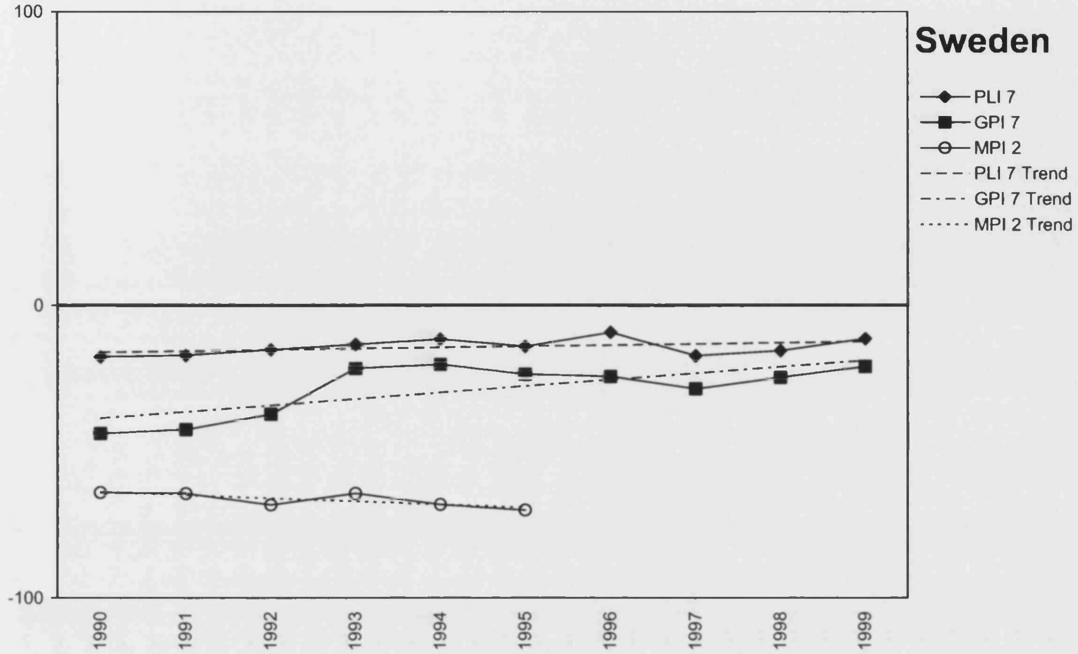
Italy
PLI 7
GPI 7
MPI 2
PLI 7 Trend
GPI 7 Trend
MPI 2 Trend



One interesting observation may be that the pollution performance of the manufacturing sector is not at all homogeneous among the countries in this cluster. The manufacturing sectors of Sweden and Finland show a statistically significant trend towards improving their pollution efficiency. The Italian manufacturing sector is also exhibiting a downward MPI 2 indicator; however, the trend does not appear to be sufficiently significant. This behaviour contrasts with the performance of the manufacturing sectors in Belgium and France, where the MPI 2 indicator appears to be trending upwards.

As seems to be the case with regard to the other 'transitory' pollution performance cluster (that is, with regard to the catching-up countries), the falling-behind-cluster is an assortment of countries with rather different characteristics. On the one hand, there are Belgium and France. Those two countries seem to exhibit a consistent overall performance pattern which clearly fits the definition of this cluster.

Table 11 *Pollution performance indicators: countries that fall behind*

	Finland	Belgium	France	Italy	Sweden
PLI 7 Trend	+0.4	**+1.5****	**+0.4***	+0.7	+0.4
Dev (PLI 7)	+5	+1	+3	-2	-14
Overall performance	Poor	Poor	Poor	Falling behind	Falling behind
GPI 7 Trend	+1.7	**+0.8***	**+0.7***	**+2.6***	**+2.2***
Dev (GPI 7)	-1	-11	-11	-3	-29
Overall performance	Falling behind	Falling behind	Falling behind	Falling behind	Falling behind
MPI 2 Trend	**-13.0***	+4.8	**+1.6***	-6.2	**-1.1***
Dev (MPI 2)	+14	+82	-40	+6	-66
Overall performance	Catching-up	Poor	Falling behind	Catching-up	Strong

* Significant at 90% level
** Significant at 99% level

On the other hand, there are three countries, Finland, Italy and Sweden, where the trends of the three pollution performance indicators do not exhibit the same sign. In other words, the pollution performance trend of the manufacturing sector in those countries appears downwards, whereas the to the overall pollution trend points upwards. One possible explanation of this behaviour may be that the major part of the overall pollution increase in those countries does not originate from the manufacturing sector but from other sources, such as road traffic or private households.

Strong pollution performers

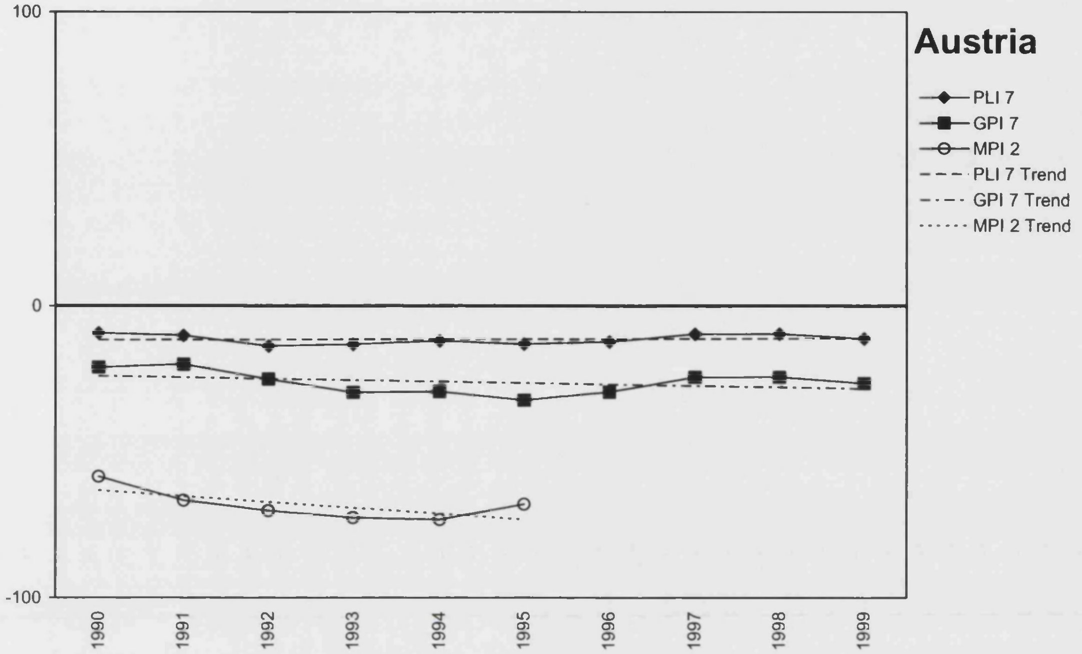
The fourth and final performance cluster consists of strong pollution performers. According to the observed performance pattern, this group consists of **Austria, Denmark, Germany, and the Netherlands**. To qualify as a strong pollution performer, countries need to exhibit low average pollution levels in combination with a lack of convergence. They therefore retain, or even expand, their pollution efficiency lead over the observation period.

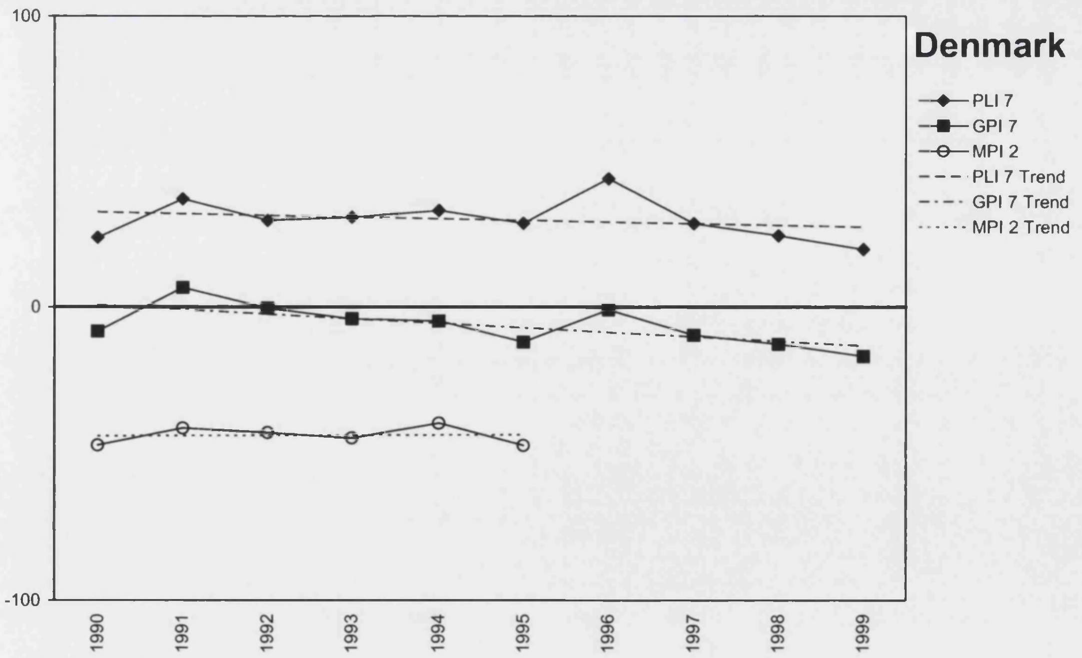
Table 12 Pollution performance indicators: strong pollution performers

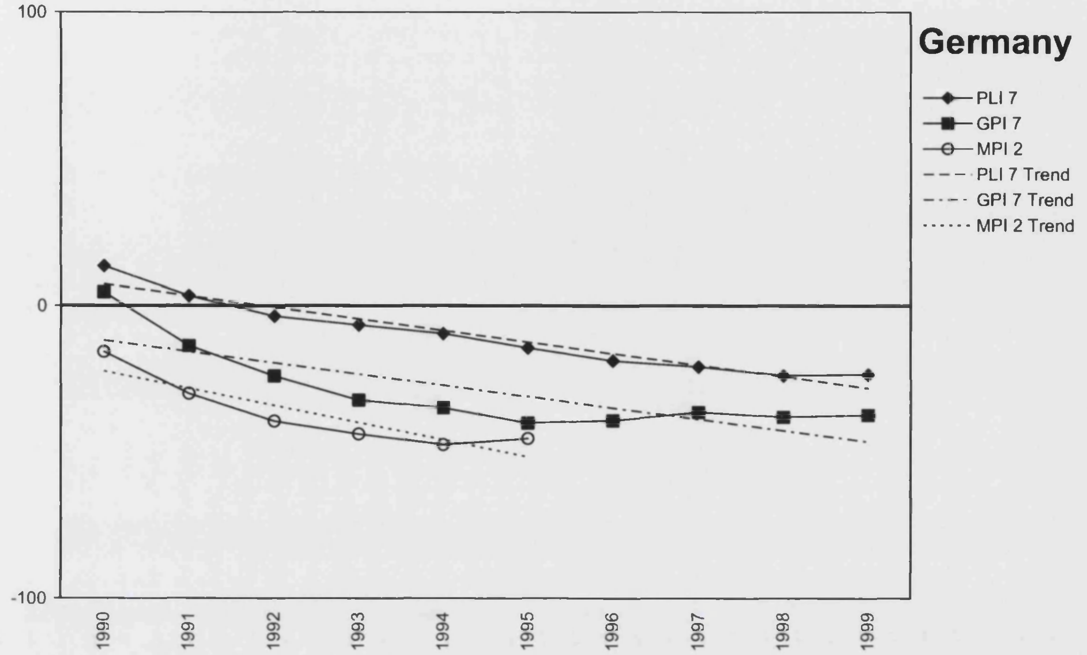
	Austria	**Denmark**	**Germany**	**Netherlands**
PLI 7 Trend	+0.0	-0.6	**-3.9****	**-1.0****
Dev (PLI 7)	-11	+30	-10	-6
Overall performance	Strong	Catching-up	Strong	Strong
GPI 7 Trend	-0.5	**-1.6***	**-3.8****	**-1.7****
Dev (GPI 7)	-26	-6	-29	-14
Overall performance	Strong	Strong	Strong	Strong
MPI 2 Trend	**-1.9***	+0.0	**-5.9***	-0.0
Dev (MPI 2)	-68	-44	-37	-7
Overall performance	Strong	Strong	Strong	Strong

* Significant at 90% level
** Significant at 99% level

Figure 33 Pollution trends: strong pollution performers







100
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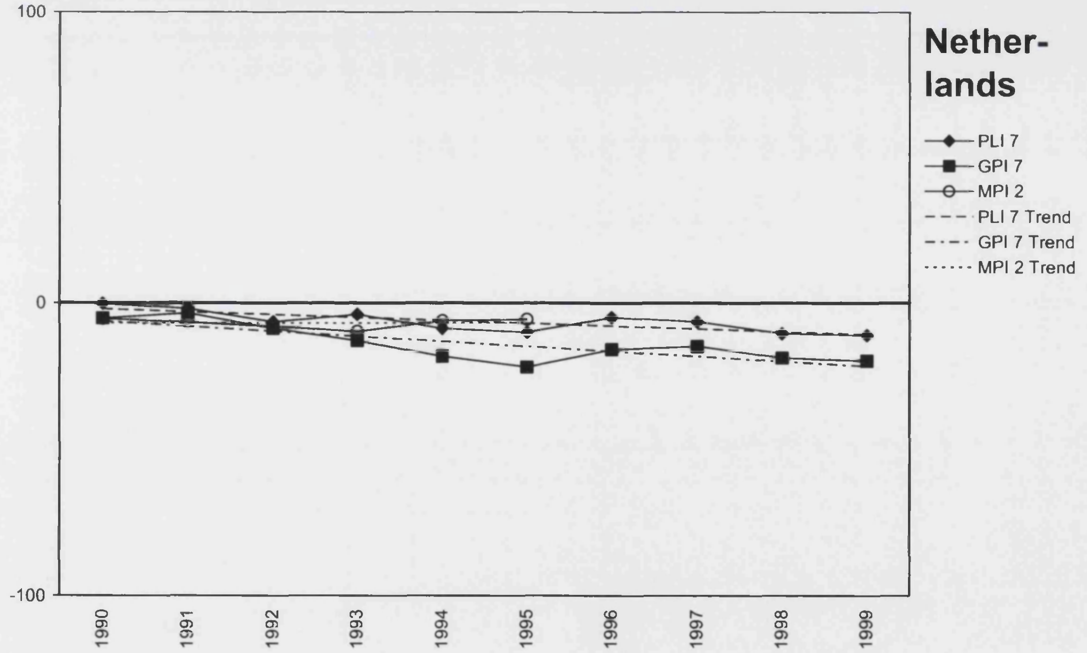
Germany
PLI 7
GPI 7
MPI 2
PLI 7 Trend
GPI 7 Trend
MPI 2 Trend



100
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Nether-
lands
PLI 7
GPI 7
MPI 2
PLI 7 Trend
GPI 7 Trend
MPI 2 Trend

Figure 33 graphically illustrates this high degree of homogeneity. The only exception to this rule is Denmark, where the overall pollution load index (PLI 7) shows a positive deviation and a negative but insignificant trend. One might wonder whether this observation would make Denmark a candidate for being part of the catching-up country cluster. However, the development of the other two pollution indicators clearly points in the direction of Denmark being a strong pollution performer, as the pollution performance of both the general economy and of the manufacturing sector appear to be consistently better than EU average. On balance, there seem to be valid reasons why the country should be considered a part of the strong pollution performer cluster, rather than of the catching-up cluster.

Conclusion

The overall results of the categorisation exercise are reported in table 13. Looking at the big picture, the two clusters at the ends of the spectrum appear to be not only rather homogeneous with regard to the observed pollution performance pattern, but also with regard to the geographic location.

Table 13 Empirical pollution performance clusters

Pollution Performance			
Poor	**In transition**		**Strong**
	Catching up	**Falling behind**	
Greece	Ireland	Belgium	Austria
Spain	Luxembourg	France	Denmark
Portugal	United Kingdom	Finland	Germany
		Italy	Netherlands
		Sweden	

With Austria, Denmark, Germany, and the Netherlands, the strong pollution performer appears to be composed of countries that have a comparable degree of economic development as well as a similar cultural and technological background. The same could be said about the poor pollution performance cluster, which consists of three Mediterranean countries.

It is the two country clusters 'in the middle' that seem to have less clear cut, but arguably more interesting country combinations. On the one hand, there is the group of countries that catch-up to the EU average in terms of pollution performance, in which the United Kingdom and Ireland are by far the most important constituents. It seems an interesting empirical observation that both countries appear to share the same pollution performance 'disposition' in spite of their quite distinct economic development over the last decades.

On the other hand, the cluster of countries which fall behind in terms of relative pollution performance seems to be an assembly of two rather different sub-groups. First, there are France and Belgium which appear to exhibit a quite analogous pollution performance pattern. Second, there is Sweden and Italy, with Finland apparently in between. It may seem odd, but Finland appears to share some pollution performance characteristics with each of the two countries mentioned before.

In terms of overall pollution performance (as expressed by the PLI and GPI indicators), Finland seems to exhibit a pattern that is by and large comparable to the Swedish one. Yet, as it is the case with regard to Italian manufacturing sector, the Finnish manufacturing industry has improved its pollution efficiency by a considerable margin up to a point at the end of the observation period when it was in line with the EU average.

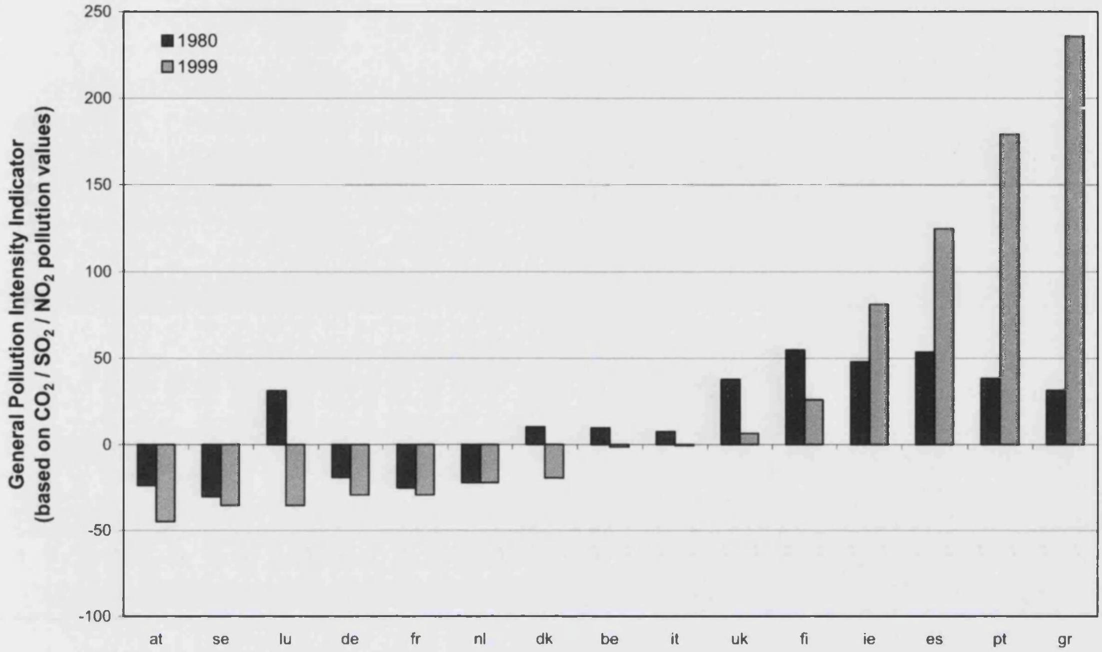
3.2.1.7 GPI 3 as lead pollution performance indicator

For the subsequent regression analyses, the General Pollution Intensity based on three air pollutants (GPI 3) will be used as proxy for pollution performance. Among the three pollution performance indicators developed for the purpose of this investigation, the GPI 3 indicator appears to represent the best compromise between long-term data availability and comprehensiveness with regard to different types of air pollutants. A more extended discussion on the advantages and disadvantages of the three indicators can be found above in section 3.2.1.5. The complete data set can be found as table 35 in the appendix.

As figure 34 illustrates, the variation between indicator values has increased over the observation period. In 1980, pollution indicator extremes were -30 of Sweden and +55 of Finland. The pollution intensity figures of all 15 countries in the sample were relatively close to the weighted average. The variation amounted to 85 indicator points. By contrast, at the end of the observation period in 1999, the variation was 281 indicator points. Austria had with -45 the lowest GPI, while Greece's pollution intensity indicator stood at +236.

This increase in variation appears to imply that the difference in pollution intensity between EU member states has gone up significantly over the observation period. In ten of the 15 countries in the sample, GPI 3 figures have decreased; four countries exhibited an increase of their pollution intensity indicator. The Netherlands scored the same GPI 3 value in 1980 and 1999.

Figure 34 General pollution intensity indicator (GPI 3)



Data Sources: NO_2 / SO_2 data from EMEP (2002)
CO_2 data from CDIAC (2002)
GDP data from Eurostat (2000)

One should keep in mind that the GPI 3 indicator mirrors the relative difference in pollution intensity between EU member states on the one hand and the weighted EU average on the other hand. A majority of countries in the sample, including the biggest EU economies, managed to decrease their pollution indicator scores. In other words, their absolute pollution figures have decreased at a higher rate than the EU average. For this reason, the increase in GPI 3 figures in Ireland, Spain, Portugal and Greece does not necessarily mean that these countries have increased their *absolute* amount of pollution. The rising indicator values merely indicate that the national pollution values decreased at a lower rate than the weighted EU average.

3.2.2 Taxes on imports and production

In its position paper on taxation, the European Chemical Industry Council (CEFIC 1999a) argued that the *"gloomy tax environment featured by the European Union"* was one of the main competitive disadvantages of chemical industries. According to that report, in 1997, the total tax revenues in Europe summed up to 41% of the GNP,[10] while that figure stood at 28% in the United States.

Apart from this gap in tax burden, CEFIC went on to argue that the structure of tax revenues also distorted the competitive position of EU chemical production. According to the analysis of CEFIC, social contribution accounted for 39 percent of total tax revenues in Europe compared to 25 percent in the United States. In turn, the tax level on labour income and corporate profits were more substantial in the U.S., where it made up 44 percent of total tax revenues in 1997 against 24 percent in the EU.

With regard to tax rates on chemical industry production factors, the CEFIC study estimated the comparative tax levels as follows.

Table 14 Tax rates on chemical industry production factors

	European Chemical Industries	U.S. Chemical industries
Taxes on corporate profits	45 %	21 %
Employers' social security charges	31 %	23 %
Non-refundable taxes on motor fuels	126 %	37 %
Non-refundable taxes on heating fuels	5 %	3 %

Source: CEFIC (1999a)

[10] CEFIC calculated that number on the basis of a weighted average for Germany, France, UK, Italy, the Netherlands and Belgium.

One should keep in mind that the said position paper was clearly aimed to carry a political message to the EU administration, and that this comparative analysis focused solely on the differences between European and U.S. tax levels, and not on differences between European Union member states. Nevertheless, this study illustrates the importance of taxation on the competitive position of chemical sectors, be it at the level of the European Union or at national level.

At present, although there appears to be some political thrust towards harmonisation in some states, there seem to be as many different tax systems across the EU as there are member states. It is therefore impossible to single out one kind of tax that is comparable and equally important to chemical industries across all member states.

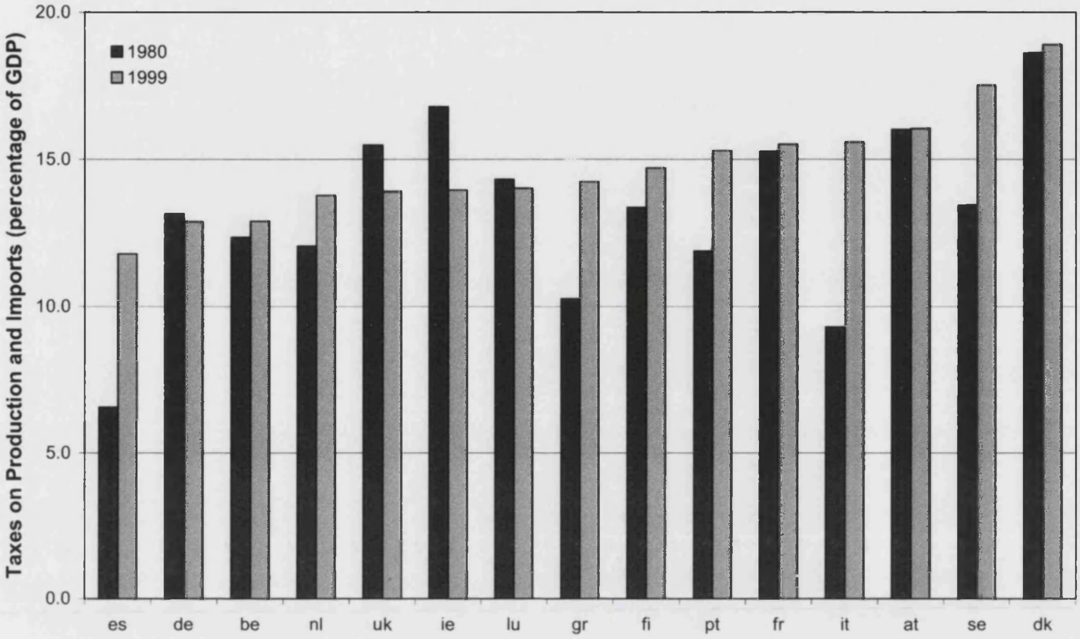
For this reason, this investigation has to resort to some kind of proxy based on an aggregate indicator. The chosen proxy is called *taxes on production and imports*. It is compiled by Eurostat as part of its Newcronos database. The indicator is defined as follows:

> *Taxes on production and imports consist of taxes payable on goods and services when they are produced, delivered, sold, transferred or otherwise disposed of by their producers plus taxes and duties on imports that become payable when goods enter the economic territory by crossing the frontier or when services are delivered to resident units by non-resident units; they also include other taxes on production, which consist mainly of taxes on the ownership or use of land, buildings or other assets used in production or on the labour employed, or compensation of employees paid.*

Eurostat, System of National Accounts (SNA) 1993, par. 7.49
from Eurostat Concepts and Definitions Database (CODED)

The time series covers all European member states over the period from 1980 to 1999. Some data points were estimated by Eurostat. In order to obtain a basis for the comparison of the tax burden across countries, the tax figures are represented as a percentage of GDP. The data is recorded as table 32 in the appendix.

Figure 35   Taxes on production and imports as % of GDP



Data Source: Eurostat, Newcronos Database (2001)

According to the Eurostat figures, Denmark was the one EU member state with the highest tax burden on production and imports both at the beginning as well as at the end of the observation period. Its tax burden was at 18.6 percent of the GDP in 1980 and at 18.9 percent in 1999. By contrast, the Spanish taxes on production and imports were the lowest among EU countries both in 1980 and 1999. Note that the Spanish tax burden was 6.6 in 1980 and 11.8 in 1999; hence, it has almost doubled over the observation period.

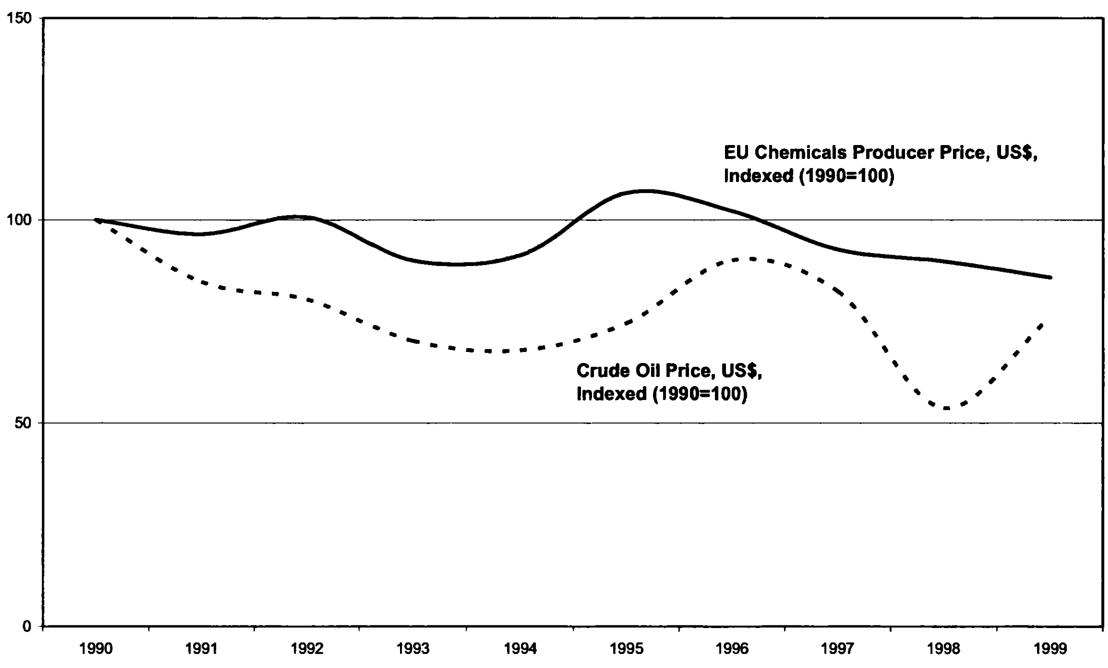
Overall, the data suggests that the tax levels in EU member states on production and imports converged significantly over the observation period, as figure 35 illustrates. The Mediterranean countries generally increased their tax burden. In some cases, such as Spain and Italy, that tax increase appears to have been quite significant. Inversely, Britain and Ireland achieved a notable reduction of their tax burden over the observation period. One rather surprising aspect contained in the Eurostat data may be that in 1999, Germany had the second lowest tax burden on production and imports.

3.2.3 Fuel price

According to the European Chemical Industry Council, one of the biggest factors in the cost of chemical production is the price of energy. In 1999, EU chemical industries spent 9 percent of their sales value on direct energy costs. This percentage was even higher with regard to the sub-sector of basic chemicals. In that industry branch, energy costs accounted for no less than 51 percent of the total sales value (CEFIC 2000b).

Figure 36 illustrates the importance of energy cost on the overall chemical producing cost using crude oil prices as example. The picture shows that, especially with regard to the period between 1990 and 1995, the price circles of crude oil and chemical producer price developed in a quite synchronised way. The correlation coefficient between the two series was 0.51.

Figure 36 EU chemicals producer price vs. crude oil price, U.S.$, Indexed (1990=100)



Data Source: CEFIC (2000b)

One could therefore make the case that relative differences in the cost of fuel should prove to be an important determinant of competitiveness of chemical industries. The regression model will take this into account by including the cost of high sulphur fuel oil for industrial customers as an energy-related independent variable.

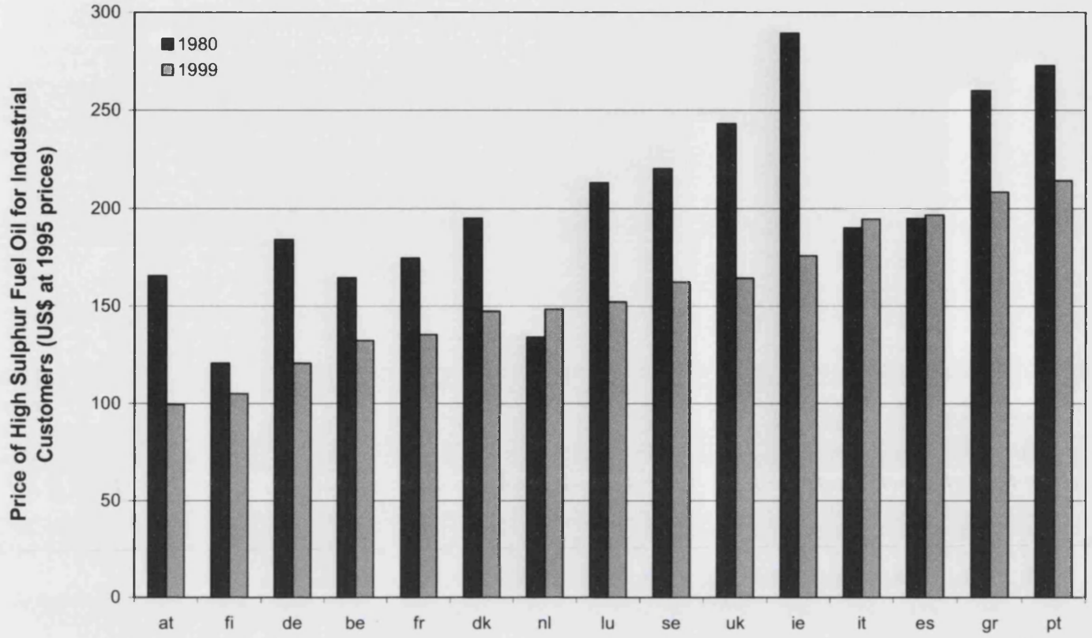
This time series was constructed from two data sets that were provided by the International Energy Agency. The basis for the data set used in this analysis is a time series on the real (constant) value of oil products for industrial customers. The series is an index with the base year 1995. It covers all EU member states over the period from 1980 to 1999.

In order to calculate absolute values, the index increments were combined with the absolute price of high sulphur fuel oil in U.S.$ per tonne (at PPP) for industrial customers. With regard to nine of the fifteen EU member states, 1995 data was available. For the rest, 1995 values had to be extrapolated using the index.[11] The index on prices of oil products was provided by the International Energy Agency Data Services in April 2001. The absolute prices of high sulphur fuel oil are of July 2002. Both data series are part of the energy price database of the International Energy Agency. The time series can be found in the appendix as table 33.

The data represented in figure 37 appears to suggest that over the observation period, fuel prices for industrial customers have decreased in twelve of the fifteen EU member states. The reduction in fuel price was particularly significant in Ireland, the UK, Austria and Germany. By contrast, fuel prices appeared to increase in the Netherlands, Italy and Spain.

[11] Absolute prices for high sulphur fuel were available for Austria, Belgium, France, Ireland, Italy, the Netherlands, Portugal, Spain and the United Kingdom. 1990 prices were available for Finland, Germany, Greece and Luxembourg. The latest data point with regard to Denmark was 1988 and with regard to Sweden 1984.

Figure 37 ***Price of high sulphur fuel oil for industrial customers, U.S.$ at 1995 prices***



Data Source: International Energy Agency, Fuel Price Database, April 2001/July 2002

The data shows that some countries have undergone particularly significant changes. In 1980, Ireland had the highest fuel price for industrial customers of all EU member states. In 1999, the highest prices could be found in Portugal, Greece, Spain and Italy, where prices were roughly twice as high as in the cheapest country, i.e., Austria.

Over the observation period, industrial fuel prices in the Netherlands increased relative to the rest of the EU. In 1980, Dutch fuel prices were the second lowest of all fifteen countries in the sample. By contrast, the Netherlands were ranking in the EU midfield in this respect in 1999.

3.2.4 Productivity of the manufacturing sector

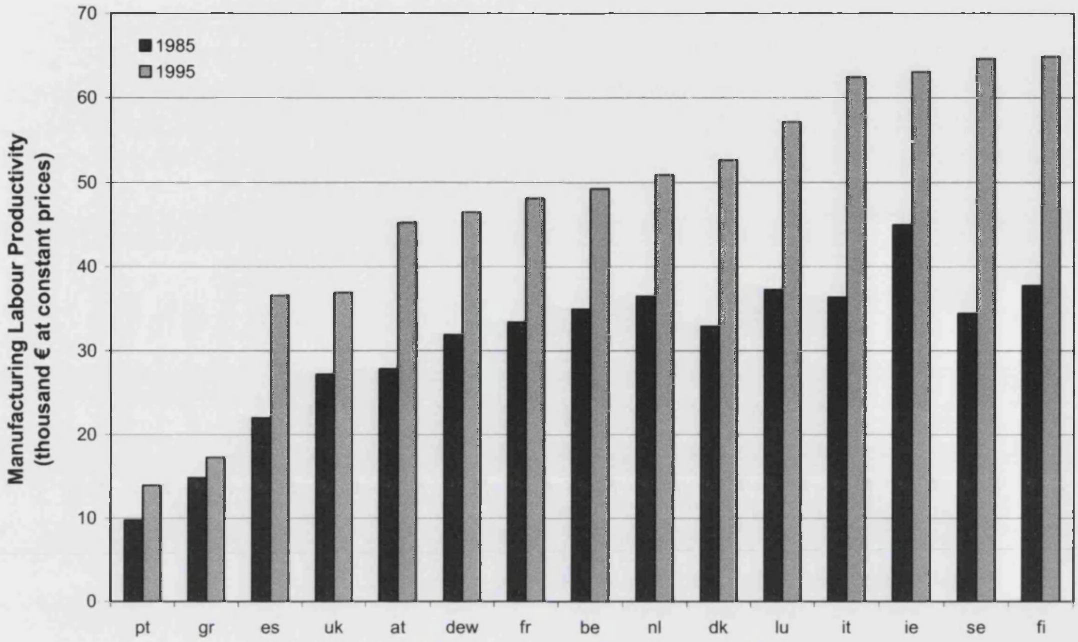
In one of its annual *Barometers of Competitiveness* (CEFIC 1998a), the European Chemical Industry Council argued that the European Union appeared to be a less attractive location for the manufacture of chemicals than the U.S. because of the following vicious circle: Weaker profits in the EU triggered lower investments, which in turn slowed down progress in labour productivity and energy efficiency. The lower investment relative to the U.S. with regard to labour productivity and energy efficiency impaired the cost competitiveness of EU chemical sectors, which closed the vicious circle.

CEFIC supported this line of argument with data from the OECD-STAN database and its own analyses, which showed that the hourly labour productivity of EU chemical industries from1990 to 1994 were 25 percent lower than in the United States.

The data series used in the subsequent regression analysis was provided by Eurostat in 2001 as part of its Newcronos database. The data set is titled labour productivity in the manufacturing sector. It comprises figures on the labour productivity of national manufacturing sectors in thousands of € per year at market exchange rates.

The data set is complete for the 15 EU member states over the period from 1985 to 1995. The German data series covers Western Germany only. With regard to seven countries, that is, Belgium, Germany, Spain, France, Luxembourg, Sweden and the United Kingdom, there are also data points for the year 1996. For all other countries, as well as for the years of the observation period 1980 to 1999 that are not covered by the data series, missing values were computed by linear projection.

Figure 38 ***Labour productivity of the manufacturing sector, thousands of € at constant prices***



Data Source: Eurostat, NewCronos Database (2001)
Original data description: Labour productivity, level (at market exchange rate)

This appeared appropriate because the available figures seemed to follow a linear evolution. The regression model was constructed both with the original data set as well as with the data set including the projections. The regression coefficients were generally robust and coherent with regard to both data sets. The data set is recorded as table 34 in the appendix.

The figures represented in figure 38 indicate that the manufacturing sectors of EU member states have increased their labour productivity between 1985 and 1995. Over that observation period, Sweden has experienced the largest rise in labour productivity – amounting to 88 percent. Inversely, with 16 percent, manufacturing labour productivity grew least in Greece.

Overall, the differences among EU member states were considerable both in 1985 as well as in 1995. At both points in time, the highest value in the sample was more than 4.5 times the lowest one.

In 1995, the countries with the highest manufacturing labour productivity in the EU were Finland, Sweden, Ireland and Italy. The last places in that ranking were taken by Portugal and Greece. Spain has improved its manufacturing labour productivity considerably between 1985 and 1995. One interesting aspect of the overall productivity pattern might be the very high figures with regard to Ireland both in 1985 and 1995.

3.2.5 GDP

A time series on the GDP of EU member states will be included in a number of regression models. This is for technical reasons mainly. The function of this independent variable will be to account for the size of the national economies in regressions where the dependent variables are expressed in absolute terms.

The data set was taken from the OECD's National Accounts database, which contained data points regarding the period 1980 to 1996. For the years 1997 to 1999, the information was obtained from the World Bank's World Development Indicators database. The composed data set was checked for consistency. There appeared to be no break in the time series.

4 Regression Analysis

4.1 The framework to the regression analysis

4.1.1 Research hypotheses

The purpose of the following regression analysis is to assess whether and in what way the relative air pollution performance of EU member states – which is used as a proxy for environmental performance – has actually had an impact on the economic performance of their chemical industries. More formally expressed, the investigation will attempt to verify the following principal hypothesis:

H_0: *Chemical industry performance **does not react** to variations in pollution performance.*

H_1: *Chemical industry performance **reacts** to variations in pollution performance.*

If the empirical data showed with a sufficient degree of statistical security that changes in pollution performance have had a significant impact on the performance of the chemical sector, H_0 could be rejected and H_1 could be considered true.

The first hypothesis, however, represents only the initial research question. If H_0 was ruled out, the analysis would then move on to assess a number of follow-up hypotheses:

$H_{1.1}$: *Chemical industry performance **deteriorates in response** to strong pollution performance.*

$H_{1.2}$: *Chemical industry performance **improves in response** to strong pollution performance.*

$H_{1.3}$: Chemical industry performance ***reacts inconclusively*** *to strong pollution performance.*

One underlying rationale behind the secondary hypotheses is to test the applicability of the conventional economic and location theories (cf. sections 2.3.1 and 2.3.4) and of the so-called Porter hypothesis (cf. section 2.2.2.1) to the particular case of EU chemical industries. These two basic approaches have distinct views on how pollution performance and economic performance interact.

Hypothesis 1.1 corresponds to the expectations of conventional economic and location theory. It bases on the assumption that rational economic agents that produce substantial amounts of pollution, such as the chemical sector, seek out regulative environments where pollution performance is relatively weak. They would tend to avoid pollution regimes that forced them to internalise pollution reduction costs into their own profit calculations.

By contrast, hypothesis 1.2 builds on the principal notion of the Porter hypothesis, which asserts that industries gained competitive advantages from reducing their emissions through innovation offsets (Porter and van der Linde 1995). In the case at hand, that approach would suggest that chemical sectors in EU member states with a strong air pollution performance would gain competitiveness through innovation offsets. The argument implies that countries with a strong pollution performance might attract or foster the development of more competitive economic sectors, because their strong pollution regime would force industries to employ technologies that secured them an advantage over competitors or newcomers in the market.

Lastly, hypothesis 1.3 implies that some national chemical sectors react more positively to strong pollution performance than others. If this hypothesis was true, the objective of the analysis would be to specify distinct reaction patterns and to look for explanations.

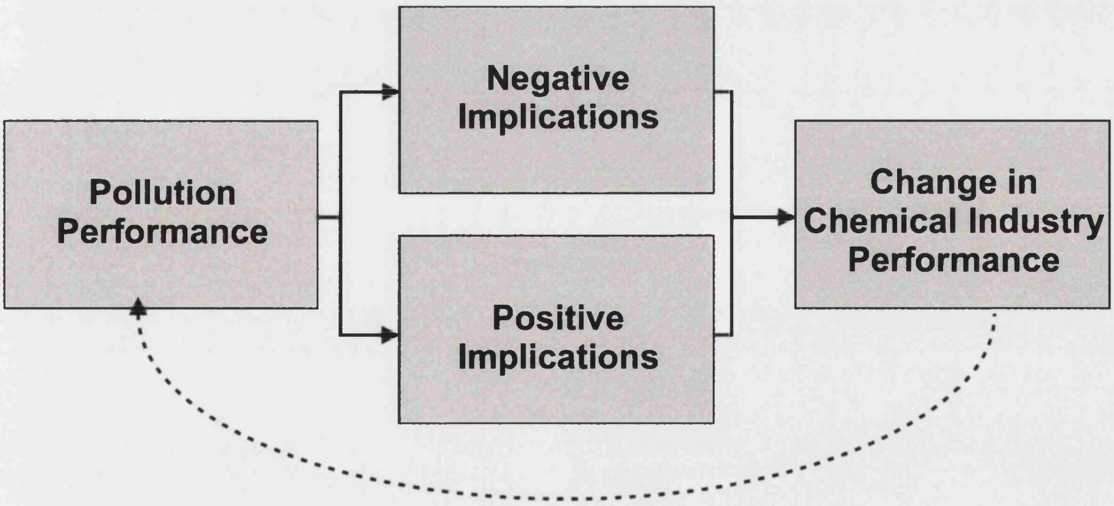
4.1.2 Theoretical model

The apparent conflict between the two principal concepts may surprise at first, and could pose the question how this investigation aims to reconcile them. How could a particular pollution performance pattern be either positive or negative with regard to chemical industry performance –or inconclusive, or even both at the same time? Furthermore, how could the regression analysis unite the two opposite implications of hypothesis 1.1 and 1.2 under one theoretical framework?

Reduced theoretical model

In order to bring together these two seemingly conflicting notions, one needs to think about the theoretical connection between pollution performance and chemical industry performance. The very basic theoretical model represented in figure 39 may serve as a starting point.

Figure 39 Reduced theoretical model



The proposed theoretical model asserts that the link between pollution performance and chemical industry performance is a causal relationship. Hence, it implies that pollution performance had a significant impact on chemical industry performance, and that therefore H_1 is valid. The rationale behind this assertion is documented in section 3.1.4.1.

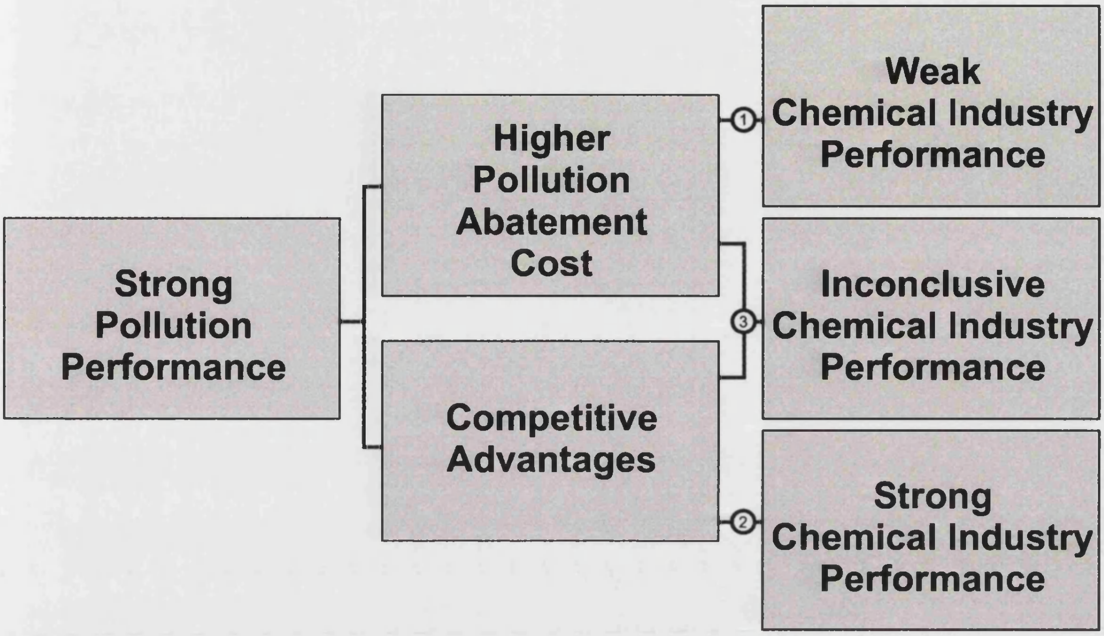
Based on this set-up, there are three possible ways in which pollution performance may be linked with chemical industry competitiveness. First, pollution performance could carry negative repercussions for chemical industry performance. Second, pollution performance might have positive implications on the chemical sector competitiveness.

However, it is also conceivable that both effects may take place at the same time. In this case, the outcome of a particular pollution performance on chemical industry performance would be a mixture between positive and negative implications. Obviously, this would be the most complicated of the three constellations, as it would indicate that both hypothesis 1.1 and hypothesis 1.2 were true to some degree at the same time.

Extended theoretical model

The extended theoretical model represented in figure 40 explains further how the causal relationship between pollution performance and chemical industry performance may function. Following the broad lines of argument of the principal theories around pollution and competitiveness, one might therefore find out empirically that strong pollution performance could indeed bring about both negative as well as positive implications for chemical industries.

Figure 40 Extended theoretical model



On the one hand, chemical sectors could suffer in strong pollution performance regimes, as they would have to spend more money for pollution abatement measures than their competitors in less strong pollution performance regimes. On the other hand, however, chemical industries in strong pollution performance regimes might also have a competitive advantage, due to innovation offsets, e.g. more efficient technologies, or through consumer preferences.

The regression analysis will have to answer which one of the two arguments stands in the case of EU chemical industries. If the negative implications of strong pollution performance dominated the equation, one would expect chemical industries to perform relatively worse than in countries with relatively poorer environmental performance. This outcome is marked in the picture as alternative 1.

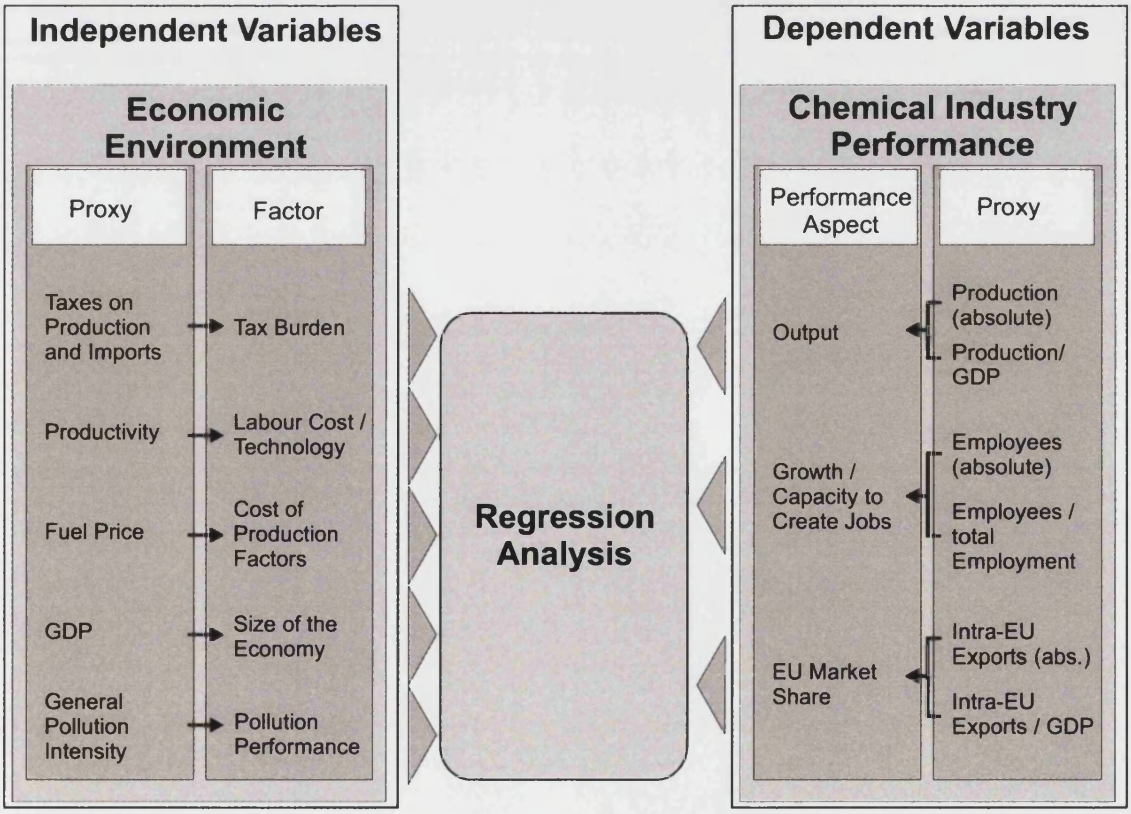
Inversely, if mainly positive implications of strong pollution performance were true, one should expect the chemical industry to perform better than in the other countries. In this case, alternative 2 in the picture was valid.

Yet, if both positive and negative implications took effect, the performance of the chemical industry should be somewhere between the two before mentioned options. The implications of strong pollution performance would therefore be neither purely positive nor negative, but mixed, as alternative 3 suggests.

4.1.3 The regression model

Of course, pollution performance is probably not the only determinant of chemical industry performance. Hence, the very simple theoretical model above could well be a theoretical starting point for the forthcoming regression analysis, but not an accurate blueprint.

Figure 41 Layout of the regression framework



The aim of the regression analysis is to estimate the strength and the direction of the impact that the independent variables exercise on the dependent variable. With regard to the research question at hand, the regression analysis should estimate to which degree and in what way chemical industry performance depends on a number of explanatory factors. Figure 41 graphically represents that basic layout of the regression analysis.

The picture illustrates that the regression analysis used in this study is based on the working assumption that four lead independent variables constitute the 'performance background' of EU chemical industries. These four factors are pollution performance, tax burden, labour cost, and energy cost. Furthermore, GDP will be introduced into some regressions as a further control variable.

As dependent variables, the regression framework operates with three chemical industry performance indicators, i.e. production, employment and exports. The three dependent variables will be expressed in both relative and absolute terms. This aims to estimate the impact of the independent variables on chemical industry performance in relation to the rest of the economy as well as in itself.

The regression model

The regression model uses pooled data from fourteen EU member states to account for changes in chemical industry performance. Note that Luxembourg was excluded from the analysis, as some of its data sets were incomplete. Therefore, the sample will comprise 14 country cases; the following investigation will refer to this country cluster as the EU 14 sample.

The following regression model will be estimated:

$$CIP_{it} = c_i + d_t + \beta_1(TAXES_{it}) + \beta_2(FUELP_{it}) + \beta_3(PRODUCTIVITY_{it}) + \beta_4(POLLU_{it}) + \epsilon_{it}$$

where CIP_{it} is the dependent variable (chemical industry production, employment, or intra-EU exports) for country i at time t. Moreover, c_i and d_t are country and time dummies respectively[12] to account for unobserved variations across countries and unobserved shocks over time. Finally, ε_{it} is the error term.

The main independent variables are tax burden on industrial production and imports (*TAXES*), fuel price (*FUELP*), productivity of the manufacturing sector (*PRODUCTIVITY*), and pollution performance (*POLLU*). The size of the national economy (*GDP*) will be included in the regression estimations only when dependent variables are used in absolute terms.

The data used in the regression model was monotonically transformed into natural log form. For this reason, the computed coefficients stand for percentage-changes (Gujarati 1978, 1995). For example, a coefficient of 1.5 would indicate that a one-percent-change in the independent variable triggers a 1.5 percent change in the dependent variable.

Panel data can be estimated using either a fixed effect model or a random effect model. The random effects assumption include all the fixed effects assumptions plus the additional requirement that the unobserved effect is independent of all explanatory variables in all time periods (Wooldridge 2000: 449). If that assumption is met, random effect models are preferable to fixed effect models because the estimators they deliver are more efficient (i.e., with smaller variance).

In order to determine whether random effects can be used to estimate the coefficients from the expression above, a Hausman specification test has been run for each dependent variable. As can be seen in the appendix 3, almost all tests confirm that random effects can be used, the exception being the regression explaining chemical industry employment in absolute terms (cf. table 48 and table 49). Therefore, random effects will be used to explain all dependent variables but employment in absolute terms where fixed effects will be used instead.

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12 The country dummies cover all 15 EU member states except Luxembourg and the UK. The UK is used as reference category Dougherty, C. (1992). Introduction to Econometrics. New York and Oxford, Oxford University Press..

A subsequent inspection of the residuals confirms the presence of first-order autocorrelation. Please refer to appendix 3 for a graphical and numerical test of autocorrelation. Heteroskedasticity, on the other hand, does not seem to be a problem in all regressions. For a graphical test for heteroskedasticity, please refer to appendix 3.

Consequently, the regression model that will be reported in the main part of this study will be a random effect GLS (general least squares) model correcting for first-order autocorrelation. There is one exception to this, namely the regression on absolute employment, which will use a corrected fixed effects model instead of a random effects one.

4.2 Regression Results

The purpose of chapter 3 was to set the foundation of the subsequent regression analysis by introducing and discussing the variables that will be used in the models. The following chapter highlights the findings of the regression analyses, which produced a substantial amount of information.

Regression models were estimated for each of the three dependent variables, both in absolute and relative terms. In addition, since there was some doubt about the reliability of the chemical industry production value data regarding Ireland (cf. section 3.1.2.1), two sets of regression models were run: one including Ireland, and another one excluding the country. By doing so, one should be able to assess the sensitivity of the regression estimates towards the inclusion of the Irish data set.

4.2.1 Models on chemical industry production

Table 15 presents the regression estimations with regard to the first dependent variable, that is, chemical industry production value. As explained earlier, the variable is represented both in relative terms (regression models 15.1 and 15.2) as well as in absolute terms (estimations 16.1 and 16.2). One should therefore remember that the first two regression estimations do *not* include 'GDP', because the dependent variable 'production value/GDP' is already normalised with a measure of the size of the economy. In contrast, the latter two regressions contain 'GDP' as independent variable in order to account for the size of the economy in the model.

The first set of regression models focus on chemical industry production performance *relative to the rest of the economy*. Therefore, the question to be answered by this set of estimations is whether the chemical sector reacts to the independent variables in a way that is distinct from the rest of the economy.

By contrast, regression models 16.1 and 16.2, where production value is expressed in absolute terms, is aimed at understanding the *immediate impact* of changes in the independent variables on production value. In other words, this set of regressions seeks to shed light on the question whether chemical industry production increases or decreases in reaction to changes in pollution performance and other independent variables.

Discussion of the regression results

The discussion of the regression results starts by looking at model 15.1, which reports the impact of the independent variables on chemical industry production value divided by GDP. In a first step, this regression was estimated using a fixed effects model. After that, a random effects GLS model was computed. In order to assess whether the random effects model could safely be used, the regression coefficients of both models were tested for systematic differences using the Hausman specification test. Since the Hausman test showed that there are no systematic differences in the coefficient values, it seemed reasonable to use the results of the random effects model that delivers more efficient coefficients, which are presented below in models 15.1. The complete set of regression estimations including the Hausman test can be found as table 42 in appendix 3.

Two out of the four independent variables show significant regression coefficients. This, in connection with the fact that the R^2 and chi^2 values seem to be sufficiently large to indicate a fair amount of reliability, appears to indicate that the explanatory variables are well chosen.

One interesting observation is that R^2-within is clearly larger than R^2-between. This points out that the development of the independent variables *over time* has a larger explanatory power on the evolution of the dependent variable than the *differences between countries* with regard to the independent variables.

Moving on to revising the regression coefficients, one could state with a high degree of confidence that the value of chemical industry production is positively associated with air pollution. Thus, countries that experienced relatively weak air pollution performances seemed to exhibit relatively higher chemical industry production. Hence, if one understands absolute chemical industry production as a measure of the sector's competitiveness, national chemical industries appeared to profit from relatively higher levels in air pollution.

Table 15 ***Regression estimates on CI production value / GDP***

CI production value / GDP		**(15.1)**		**(15.2)**	
		IE included		**IE excluded**	
TAXES		-0.4	(0.00)	-0.4	(0.01)
FUEL PRICE		+0.0	(0.70)	+0.1	(0.10)
PRODUCTIVITY		+0.1	(0.33)	+0.1	(0.13)
GDP		—		—	
POLLUTION		+0.2	(0.00)	+0.2	(0.00)
(Constant)		-3.9	(0.00)	-4.5	(0.00)
	within	0.47		0.63	
R^2	between	0.22		0.18	
	overall	0.26		0.25	
Wald chi^2		604.71	(0.00)	688.13	(0.00)
N		280		260	
Residual DF		243		224	

Note: Random effects GLS regression, corrected for first-order autocorrelation.
Group variable: country; year dummies included.
P-values in brackets.

The regression coefficients estimated by model 15.1 further indicate that 'taxes' are negatively linked to chemical industry production and significant. In contrast, 'fuel price' and the 'productivity' of the manufacturing sector appear to be positively linked to chemical industry production, but were found to be not significantly different from zero.

All findings seem to correspond well to theoretical expectations. The variable 'taxes' aims to reflect differences in the taxation of production and imports; it seems obvious that differences in tax levels over time or across countries should have negative repercussions on chemical industry competitiveness. Furthermore, since the type of taxes covered by this indicator affects the manufacturing sector – such as the chemical industry – relatively more than the general economy, the empirically observed negative impact seems intuitively justifiable.

Superior manufacturing productivity may, on the other hand, be a hint at technological advantages or beneficial structural differences. Countries with relatively higher productivity seem to have a competitive advantage, which in turn should increase their chemical industry's production. For this reason, the observed positive link, although not statistically significant, also appears in line with theoretical expectations.

Finally, the computed regression coefficients of model 15.1 also show that differences in the price of fuel have had virtually no perceivable impact on the value of chemical industry production.

Last but not least, based on these findings, the regression results provide grounds to refute the null hypothesis stated in section 4.1.1 with regard to relative chemical industry production as dependent variable and the EU 14 country cluster as reference framework. The estimations seem to confirm that pollution performance has a significant and considerably large impact on the development of chemical industry production value. For this reason, the regression results would verify hypothesis 1.1, which states that chemical industry performance deteriorates in response to strong pollution performance.

Regression model 15.2, in which Ireland is excluded from the sample, confirms the above findings. Again, the result of the Hausman test justifies the reporting of the random effect model results (cf. table 43 in appendix 3). The coefficients of all independent variables are almost identical in both estimations. One could, therefore conclude with some confidence that the regression results are robust towards the exclusion of Ireland from the sample.

Regression models 16.1 and 16.2 estimate the impact of the independent variables – this time, including 'GDP' – on chemical industry production in absolute terms. Once more, the two models reported are random effects estimations (cf. table 44 and table 45 in appendix 3). In broad terms, they appear to confirm once more the direction and size of the regression coefficients observed before. The only exceptions to this rule are shown in model 16.2 where Ireland is excluded from the sample. In that regression estimation, 'productivity' shows up to be significant at 10% significance level, and 'pollution' is found to be not significantly different from zero.

Table 16 Regression estimates on CI production value, absolute terms

CI production value, abs. terms		(16.1) IE included		(16.2) IE excluded	
TAXES		-0.4	(0.00)	-0.4	(0.00)
FUEL PRICE		+0.0	(0.95)	+0.1	(0.12)
PRODUCTIVITY		+0.1	(0.46)	+0.1	(0.06)
GDP		+0.7	(0.00)	+0.6	(0.00)
POLLUTION		+0.1	(0.01)	+0.1	(0.24)
(Constant)		-0.2	(0.84)	+1.6	(0.12)
	within	0.65		0.75	
R^2	between	0.90		0.90	
	overall	0.88		0.88	
Wald chi^2		267.47	(0.00)	311.99	(0.00)
N		280		260	
Residual DF		242		223	

Note: Random effects GLS regression, corrected for first-order autocorrelation.
Group variable: country; year dummies included.
P-values in brackets.

The newly introduced independent variable 'GDP' has the largest coefficient and is shown to be highly significant. Again, this behaviour seems in line with theoretical expectations –it seems obvious that the production volume of chemical industries depends in no small part on the absolute size of the economy. This observation and the observation that the R^2-between value in models 16.1 and 16.2 is relatively higher than in models 15.1 and 15.2 respectively, seems to suggest that differences between countries concerning the independent variable 'GDP' explain a good part of the development of the dependent variable.[13]

[13] Obviously, the explanatory variables are held in different units, and, as a result of this, their coefficients cannot be directly compared. However, since all variables were transformed into natural log form, the results reported here indicate that a change of x percent in the explanatory variable appears to have an impact of y percent in the development of the dependent variable (cf. section 4.1.3).

Considering what has been said about, for example, the Irish economic boom and its impact on the development of the Irish chemical industry, this observation appears plausible.

Actual versus predicted change

Based on the results of the regression models presented above, it is now possible to compare the actual development of the dependent variable to the predicted changes by the model. Using the computed regression coefficients of estimation 15.1, one can estimate the individual contribution of each independent variable to the overall predicted change.

To do this, the actual change of each independent variable is multiplied by its estimated coefficient. In other words, the computed regression model renders an estimation of the individual impact of each independent variable, which can be compared to the actual, empirically observed, change. Taken together, the individual impacts of all independent variables will add up to the overall predicted change of the dependent variable. Table 17 reports the results of this exercise with regard to regression model 15.1, which established an estimation using the relative chemical industry production value as the dependent variable.

In order to compare the differences in the impact of the independent variables across the pollution performance clusters (cf. section 3.2.1.6), the countries are ordered by poor pollution performers, catching-up countries, falling-behind countries, and strong pollution performers.

Table 17 *Actual and predicted changes: CI production value / GDP*

Chemical Industry Production / GDP, 1980-1999

Poor pollution performers	**gr**	**es**	**pt**	**AVG**
Actual Change	-3%	4%	-16%	**-5%**
Predicted Change	61%	38%	62%	**54%**
contribution to the predicted change				
TAXES	-18%	-30%	-14%	**-21%**
FUEL PRICE	-1%	0%	-1%	**-1%**
PRODUCTIVITY	1%	10%	5%	**5%**
POLLUTION	26%	10%	19%	**18%**
(year)	53%	49%	53%	**51%**

Countries that catch up	**ie**	**uk**	**AVG**
Actual Change	815%	20%	**417%**
Predicted Change	76%	54%	**65%**
contribution to the predicted change			
TAXES	11%	6%	**8%**
FUEL PRICE	-2%	-1%	**-2%**
PRODUCTIVITY	6%	5%	**6%**
POLLUTION	6%	-7%	**-1%**
(year)	55%	52%	**53%**

Countries that fall behind	**be**	**fr**	**fi**	**it**	**se**	**AVG**
Actual Change	99%	67%	22%	4%	111%	**61%**
Predicted Change	52%	55%	52%	29%	53%	**48%**
contribution to the predicted change						
TAXES	-2%	-1%	-5%	-25%	-14%	**-10%**
FUEL PRICE	-1%	-1%	-1%	0%	-1%	**-1%**
PRODUCTIVITY	7%	7%	12%	9%	19%	**11%**
POLLUTION	-3%	-1%	-6%	-2%	-2%	**-3%**
(year)	51%	52%	51%	47%	51%	**50%**

Strong pollution performers	**at**	**dk**	**de**	**nl**	**AVG**
Actual Change	37%	85%	0%	74%	**49%**
Predicted Change	52%	50%	56%	50%	**52%**
contribution to the predicted change					
TAXES	0%	-1%	1%	-7%	**-2%**
FUEL PRICE	-2%	-1%	-2%	0%	**-1%**
PRODUCTIVITY	12%	10%	9%	6%	**9%**
POLLUTION	-9%	-8%	-4%	0%	**-5%**
(year)	51%	51%	52%	51%	**51%**

Calculations based on regression model 15.1

Taking Belgium as an example, regression model 15.1 would predict a proportional increase in relative chemical industry production of 52 percent. The actual increase, however, was 99 percent, which indicates that the regression model predicts around half of the actual increase in chemical industry production.

With regard to the impact of the distinct independent variables on absolute chemical industry production, table 17 disaggregates the overall predicted change into the individual contributions of 'taxes', 'fuel price', 'productivity', 'GDP', 'pollution', and the time-dummies 'year'.

According to the regression estimations, and keeping Belgium as an example, the actual development in 'taxes' over the observation period 1980 to 1999 has contributed a predicted decrease of -2 percent in relative chemical industry production. In other words, since the tax burden with regard to production and import taxes has gone up in Belgium over the observation period, and since this variable is negatively associated with the development of the absolute production value, the evolution of 'taxes' in itself would imply a negative development in the dependent variable. The input to the predicted change by the independent variable 'fuel price' appeared to be -1 percent. Last but not least, changes in 'pollution' have contributed some -3 percent to the development of the chemical industry production value / GDP over the observation period.

These negative contributions of 'taxes', 'fuel price' and 'pollution' were partly set off by the developments of the other explanatory factors. The increase in 'productivity' in the Belgian manufacturing sector contributed a predicted increase of +7 percent to the overall development of chemical industry production. However, the biggest projected contribution clearly comes from the auxiliary independent variable 'year', which is a dummy variable that captures all unidentified time shocks that have hit the EU countries in the sample.

Based on the information contained in the regression model, one could only speculate as to what unobserved trends or developments hide behind the dummy variable 'year'. Possible explanations might include external shocks such as the accession of new EU member states or the reunification of Germany, or a general increase in European and world trade activity.

Looking at the bigger pattern of actual and predicted changes across the countries in the sample, there seem to be considerable differences both among individual countries as well as among country clusters. To start with, the model predicts very accurately the actual change in chemical industry production among strong pollution performers and among countries that fall behind. On the other hand, chemical industry production in poor pollution performance countries, and in catching-up countries, does not appear to be comprehensively explained by the independent variables in this model.

With regard to the poor pollution performers' cluster, one can observe that some countries experienced a negative actual change. In other words, the production value of the chemical sector in Greece and Portugal did not grow as much as the general economy over the course of the observation period. Thus, judging from this development, the Greek and Portuguese chemical sectors were less competitive than the rest of the economy.

Turning to the contribution of the independent variables, and focusing first on the variable of our interest, that is, pollution performance, we observe that across the poor air pollution performers' cluster, in average, 'pollution' contributed +18 percent to the predicted increase in relative chemical industry production. In other words, relative chemical industry production in this cluster has profited very much from the poor pollution performance among the three Mediterranean countries.

Overall, the results of the regression model seem to suggest that the predicted contribution of 'pollution' among poor pollution performers was very considerable, only second to 'taxes' with an average predicted contribution of -21 percent. In Greece and Portugal, 'pollution' appears to be even the single largest independent variable covered in this analysis. The other two explanatory factors appear to have a much smaller average impact. However, one should also keep in mind that the average predicted contribution of the time-dummies was +51 percent.

If one considers the strong air pollution performers Austria, Denmark, Germany and the Netherlands, 'pollution' has had the opposite effect: its average contribution to relative chemical industry production was -5 percent. In other words, the relatively strong pollution performance of those countries has had a perceivable negative impact on their chemical industries, as the sector's production value relative to the GDP decreased over the observation period.

Again, pollution performance was the second biggest contributor after 'productivity'. It may be worth taking note that the biggest contributing factor varies between poor and strong pollution performers: productivity is positively associated with the dependent variables for the strong performance cluster, and much less so with regard to the poor pollution performers.

Adding up the positive contribution of 'pollution' among poor pollution performers (+18%) to its negative contribution among strong pollution performers (-5%), one arrives to the conclusion that distinct pollution performance patterns among EU member states accounted for 23 percent of the difference in the development of their chemical industry production value / GDP.

Table 18 Actual and predicted changes: CI production value, absolute terms

Absolute Chemical Industry Production, 1980-1999

Poor pollution performers	gr	es	pt	AVG
Actual Change	36%	60%	81%	**59%**
Predicted Change	118%	104%	205%	**142%**
contribution to the predicted change				
TAXES	-20%	-34%	-19%	**-24%**
FUEL PRICE	0%	0%	0%	**0%**
PRODUCTIVITY	1%	9%	5%	**5%**
GDP	38%	46%	105%	**63%**
POLLUTION	21%	8%	19%	**16%**
(year)	78%	75%	95%	**83%**

Countries that catch up	ie	uk	AVG
Actual Change	2219%	75%	**1147%**
Predicted Change	282%	130%	**206%**
contribution to the predicted change			
TAXES	16%	7%	**11%**
FUEL PRICE	-1%	0%	**0%**
PRODUCTIVITY	7%	5%	**6%**
GDP	145%	44%	**94%**
POLLUTION	6%	-6%	**0%**
(year)	109%	81%	**95%**

Countries that fall behind	be	fr	fi	it	se	AVG
Actual Change	125%	97%	68%	48%	122%	**92%**
Predicted Change	85%	95%	113%	86%	73%	**90%**
contribution to the predicted change						
TAXES	-2%	-1%	-6%	-29%	-14%	**-10%**
FUEL PRICE	0%	0%	0%	0%	0%	**0%**
PRODUCTIVITY	6%	6%	11%	8%	15%	**9%**
GDP	13%	17%	35%	37%	5%	**21%**
POLLUTION	-2%	-1%	-4%	-2%	-1%	**-2%**
(year)	72%	74%	77%	72%	69%	**73%**

Strong pollution performers	at	dk	de	nl	AVG
Actual Change	100%	162%	43%	118%	**106%**
Predicted Change	126%	118%	126%	95%	**116%**
contribution to the predicted change					
TAXES	0%	-1%	1%	-8%	**-2%**
FUEL PRICE	0%	0%	0%	0%	**0%**
PRODUCTIVITY	11%	9%	8%	5%	**8%**
GDP	43%	39%	40%	23%	**36%**
POLLUTION	-7%	-7%	-3%	0%	**-4%**
(year)	80%	78%	80%	73%	**78%**

Calculations based on regression model 16.1

Moving on to table 18, the dependent variable now changes to be expressed in absolute terms. The figures represented in this table seem to differ from what has been said before in a number of ways. The actual changes are much bigger in absolute terms than in relative terms. This could be explained by the fact that the relative production value captured the chemical industry growth *in excess* of the (generally positive) growth of the general economy. Since the absolute production value indicator reports the chemical sector's development on a 'stand-alone' basis, these figures should be higher. In other words, an explanation for this difference is the fact that 'GDP' is now included as a separate independent variable.

With regard to the contribution of each independent variable, the predicted impact of 'GDP' is the most important contributing factor among all independent variables, followed by 'taxes' and 'pollution'. Again, this observation could serve as one more confirmation that the overall evolution of the economy is the major explanatory factor for the development of the chemical industry production volume.

The importance of the dummy variable 'year' has increased across all countries in the sample. Thus, the importance of unidentified time shocks is bigger with regard to chemical industry production in absolute terms than with regard to chemical industry production value in relative terms.

Finally, the contribution of 'pollution' to absolute chemical industry production is smaller than to production in relative terms. This could be an indication that the production performance of the chemical sector relative to the general economy is more sensitive to differences in pollution performance than the chemical production in absolute terms.

Chemical industry production and pollution performance: an interim conclusion

The regression models presented in this section have produced a quite robust picture about the relationship between chemical industry production and the independent variables.

In general, 'taxes' appear to be significant and negatively linked to chemical industry production. Moreover, they are among the most important contributing factors, along with 'productivity' and 'pollution', irrespective of whether the dependent variable is expressed in absolute or relative terms. The finding that differences in 'productivity' are positively linked to chemical industry production value seems equally robust. Finally, the regression estimations have consistently shown that 'pollution' has a positive impact on the dependent variable.

Overall, the contribution of 'pollution' to the development of chemical industry production was shown to be considerable vis-à-vis the other explanatory variables. This observation is in line with the literature, which generally notes that environment-related factors are typically not the biggest, but one among the most important determinants of economic competitiveness.

In terms of the overall difference in chemical industry production that is caused by distinct pollution performance patterns of EU member states, the impact of pollution performance appears to be very significant. With regard to production value relative to GDP, the overall impact seemed to make a difference of up to 35 percent, ranging from +26 percent in the case of Greece, to -9 percent regarding Austria. In absolute terms, the overall impact appeared to be somewhat smaller with 28 percent.

4.2.2 Models on chemical industry employment

The following set of regression models establishes the relationship between the independent variables and chemical industry employment. The basic structure of the regression models and of the tables in which they are presented here is the same as in the previous section.

Table 19 shows the estimated impact of the independent variables on relative chemical employment, that is, the percentage of chemical industry employees in the total workforce of a country. Model 19.1 includes Ireland into the sample, while model 19.2 reports the results of the regression estimation when we exclude the country. Later, models 20.1 and 20.2 will report regression coefficients for *absolute* chemical industry employment as the dependent variable.

The Hausman specification test failed to confirm that a random effect model could safely be used with regard to regression estimations 20.1 and 20.2. Therefore, the results reported in the main part of this thesis for these two models are first-order autoregressive fixed effect regressions. The detailed results of the regression analysis can be found as table 48 and table 49 in appendix 3.

Table 19 Regression estimates on CI employment / total workforce

CI employment / total workforce		(19.1) **IE included**		(19.2) **IE excluded**	
TAXES		-0.1	(0.54)	-0.0	(0.84)
FUEL PRICE		-0.0	(0.75)	-0.0	(0.55)
PRODUCTIVITY		+0.1	(0.10)	+0.1	(0.06)
GDP		—		—	
POLLUTION		-0.0	(0.88)	-0.0	(0.83)
(Constant)		+0.2	(0.68)	+0.2	(0.74)
	within	0.16		0.22	
R^2	between	0.42		0.46	
	overall	0.25		0.30	
Wald chi²		24.04	(0.46)	28.57	(0.24)
N		280		260	
Residual DF		243		224	

Note: Random effects GLS regression corrected for first-order autocorrelation.
Group variable: country; year dummies included.
P-values in brackets.

The first fundamental observation, which will set the general tone of the subsequent discussion of the regression results on chemical industry employment, must be a word of caution: the chi² values of regression models 19.1 and 19.2, as well as the F values of estimations 20.1 and 20.2, are too low to reject the hypothesis that all coefficient are zero. In other words, the statistical relationships between the explanatory variables and the development of chemical industry employment are not strong enough to establish underlying causalities with a sufficiently high degree of certainty.

Table 20 ***Regression estimates on CI employment, absolute terms***

CI employment, absolute terms		**(20.1) IE included**		**(20.2) IE excluded**	
TAXES		-0.0	(0.79)	+0.0	(0.89)
FUEL PRICE		+0.0	(0.46)	+0.0	(0.76)
PRODUCTIVITY		+0.1	(0.12)	+0.1	(0.12)
GDP		+0.0	(0.59)	+0.0	(0.83)
POLLUTION		-0.0	(0.68)	-0.0	(0.62)
(Constant)		+3.0	(0.00)	+3.5	(0.00)
	within	0.09		0.10	
R^2	between	0.56		0.33	
	overall	0.42		0.22	
F		0.97	(0.50)	1.06	(0.40)
N		280		260	
Residual DF		229		211	

Note: Fixed effects regression corrected for first-order autocorrelation.
Country dummies and year dummies included.
P-values in brackets.

Therefore, one could only make a couple of limited observations regarding the regression results. First of all, the R^2-between values of all regression models appear to be higher than the R^2-within values. This might be taken as an indication that the observed differences regarding the independent variables between countries has more explanatory power than the development of the independent variables over time. In other words, structural differences between countries seem to have a bigger impact on the development of chemical industry employment than changes in the explanatory variables over the observation period. That observation is consistent with the notion that employment is caused by institutional factors, which vary greatly across countries but not so much across time.

Second, the only explanatory variable that appears to have some significance with regard to chemical industry employment is 'productivity'. In model 19.2, this factor was shown to be significant at 10 percent significance level. With regard to the three other models, the P-values appeared to be just below that threshold. Therefore, one could state with some moderate degree of confidence that differences in the productivity of the manufacturing sector were positively linked to chemical industry employment levels, especially when the dependent variable is measured in relative terms. As mentioned above, such behaviour appears to be in line with theoretical expectations.

Third, and most importantly in the context of this study, the regression coefficient of the 'pollution' indicator turns out to be not significantly different from zero in all four models. Based on this observation, the null hypothesis of this study cannot be rejected. In other words, the empirical analysis does not provide any evidence that differences in pollution performance among EU member states have had an impact on the employment performance of their chemical industries.

Concluding remarks

One could sum up the findings in this section into three points: first, the regression models do not seem satisfactory in terms of reliability and robustness. Second, they might show that 'productivity' is positively linked to chemical industry employment, while all other explanatory variables fail to achieve significance. Finally, the regression results appear to indicate that pollution performance has little impact on the creation or destruction of jobs in the EU chemical sector, which seems to be more related to the existing labour market institutions in each country.

These findings correspond to earlier results of Levinson (2000) and Morgenstern et al. (2001), which show that increased environmental taxes or spending, respectively, did not generally cause a significant change in employment levels. Both studies conclude that their data does not support the notion of a jobs-versus-the-environment trade-off.

4.2.3 Models on intra-EU chemical industry exports

The third and final set of regression models tests the impact of the independent variables on intra-EU chemical industry exports. Again, the system in which the results are presented here corresponds to the earlier two sections.

Table 21 presents the results of the regression estimations relating to intra-EU chemical industry exports as a percentage of GDP. Models 21.1, 21.2 and 22.1 were estimated as random effects models, while model 22.2 – which refers to intra-EU exports in absolute terms excluding Ireland – failed to pass the Hausman specification test. Therefore, that estimation was based on a fixed effects regression. Based on the observed R^2, chi^2 or F values, all estimations appear to exhibit a high level of significance concerning the overall set of independent variables. For details on the regression analysis, please refer to annex 3.

With regard to all four regression models, the R^2-within value was the highest observed indicator among all R^2 values. This seems to indicate that the development of the independent variables over time has had a higher explanatory power than structural differences between countries.

Table 21 ***Regression estimates on CI intra-EU exports / GDP***

Intra-EU exports / GDP		**(21.1) IE included**		**(21.2) IE excluded**	
TAXES		-0.2	(0.39)	-0.1	(0.81)
FUEL PRICE		-0.2	(0.29)	-0.3	(0.06)
PRODUCTIVITY		+0.4	(0.02)	+0.5	(0.00)
GDP		—		—	
POLLUTION		+0.3	(0.01)	+0.2	(0.03)
(Constant)		-6.3	(0.00)	-6.2	(0.00)
	within	0.79		0.78	
R^2	between	0.26		0.24	
	overall	0.23		0.25	
Wald chi^2		189.47	(0.00)	163.16	(0.00)
N		126		117	
Residual DF		100		92	

Note: Random effects GLS regression corrected for first-order autocorrelation.
Group variable: country; year dummies included.
P-values in brackets.

Regression model 21.1 indicates that there are two independent variables with a statistically significant impact on the development of intra-EU chemical industry exports in relative terms. One of them is 'productivity', which is positively linked with exports. The other one is 'pollution', which is also shown to have a positive impact on chemical industry exports relative to the general economy.

In other words, our lead independent variable appears to have a very sizeable impact on the export performance of chemical industries, second only to the impact of 'productivity'. Considering that productivity differences translate into production costs, and given the paramount importance of price as a competitive advantage in the global market, the impact of 'productivity' on export levels may not come as a big surprise. The empirically observed importance of 'pollution', however, is remarkably large.

The coefficients of the two other independent variables, 'taxes' and 'fuel price', were not significantly different from zero. Thus, neither differences in taxation nor differences in the price of fuel appeared to make a difference with regard to the export performance of chemical industries.

By and large, regression model 21.2, where Ireland is excluded from the sample, confirms the above conclusions. The only major finding that differs from the earlier regression model concerns the independent variable 'fuel price', which is reported to be significant and negatively linked to relative chemical industry exports. Given that a large proportion of chemical industry raw materials are petrochemicals, this finding appears in line with theoretical expecatations.

Moving to regression models 22.1 and 22.2, which report the impact of the independent variables on intra-EU exports of chemical industries in absolute terms, the picture seems to change in a number of ways. First, the R^2-between values of the regression estimations increase. This could be an indication that structural differences across countries have a larger impact on chemical industry exports in absolute terms than on exports in relative terms.

Table 22 ***Regression estimates on CI intra-EU exports, absolute terms***

Intra-EU exports, absolute terms		**(22.1) IE included(1)**		**(22.2) IE excluded(2)**	
TAXES		-0.3	(0.32)	+0.3	(0.21)
FUEL PRICE		-0.1	(0.33)	-0.2	(0.13)
PRODUCTIVITY		+0.4	(0.01)	+0.1	(0.50)
GDP		+0.6	(0.00)	+0.2	(0.36)
POLLUTION		+0.1	(0.32)	-0.1	(0.59)
(Constant)		-0.9	(0.70)	+6,5	(0.00)
	within	0.85		0.76	
R^2	between	0.66		0.68	
	overall	0.66		0.62	
Wald chi²		275.35	(0.00)		
F				21.09	(0.00)
N		126		104	
Residual DF		99		79	

Note: (1) Random effects GLS regression corrected for first-order autocorrelation.
Group variable: country; year dummies included.
(2) Fixed effects regression with robust standard errors corrected for first-order autocorrelation.
Country dummies and year dummies included.

P-values in brackets.

Second, with regard to model 22.1, 'productivity' remains significant and positively linked to absolute chemical industry production, while 'pollution' is not statistically different from zero. In other words, while productivity is still shown to be a competitive advantage in terms of absolute chemical exports to the EU, differences in the pollution performance of countries appear to lose their importance. However, we have to take this result with caution, as table 22 casts some doubt on the regression model explaining absolute exports as a whole. The reason for this is that the estimation results do not appear to be robust to the exclusion of Ireland.

Table 23 Actual and predicted changes: CI intra-EU exports / GDP

Chemical Industry Intra-EU Exports / GDP, 1980-1999

Poor pollution performers	**gr**	**es**	**pt**	**AVG**
Actual Change	1%	114%	21%	**45%**
Predicted Change	81%	96%	91%	**89%**
contribution to the predicted change				
TAXES	-1%	-4%	-3%	**-2%**
FUEL PRICE	-2%	-3%	1%	**-1%**
PRODUCTIVITY	9%	21%	17%	**16%**
POLLUTION	15%	20%	13%	**16%**
(year)	60%	63%	62%	**62%**

Countries that catch up	**ie**	**uk**	**AVG**
Actual Change	174%	51%	**112%**
Predicted Change	83%	48%	**65%**
contribution to the predicted change			
TAXES	4%	-2%	**1%**
FUEL PRICE	1%	-2%	**0%**
PRODUCTIVITY	12%	9%	**10%**
POLLUTION	5%	-10%	**-3%**
(year)	60%	54%	**57%**

Countries that fall behind	**be**	**fr**	**fi**	**it**	**se**	**AVG**
Actual Change	105%	85%	200%	99%	122%	**122%**
Predicted Change	72%	75%	100%	80%	117%	**89%**
contribution to the predicted change						
TAXES	-2%	-1%	1%	-10%	1%	**-2%**
FUEL PRICE	-1%	-2%	3%	-2%	7%	**1%**
PRODUCTIVITY	15%	13%	23%	21%	34%	**21%**
POLLUTION	2%	6%	9%	11%	8%	**7%**
(year)	58%	59%	64%	60%	66%	**61%**

Strong pollution performers	**at**	**dk**	**de**	**nl**	**AVG**
Actual Change	60%	125%	23%	23%	**58%**
Predicted Change	80%	60%	53%	57%	**63%**
contribution to the predicted change					
TAXES	-1%	-2%	0%	-3%	**-2%**
FUEL PRICE	1%	-10%	1%	-4%	**-3%**
PRODUCTIVITY	19%	18%	16%	11%	**16%**
POLLUTION	1%	-2%	-18%	-3%	**-5%**
(year)	60%	56%	55%	56%	**57%**

Calculations based on regression model 23.1

Actual and predicted changes

Table 23 reports the actual and predicted changes with regard to the dependent variable, intra-EU chemical industry exports expressed in relative terms, while table 24 relates to absolute export figures. Overall, both the actual as well as the predicted changes are smaller when the dependent variable is expressed in relative terms. Based on this observation, one might conclude that the value of chemical industry exports to the European common market grew at a lesser rate than the respective national economies.

With regard to the lead independent variable, 'pollution', table 23 reveals at least two important findings. First, in Greece (+15%) and the United Kingdom (-9%), pollution performance is predicted to be the single most important contributing factor to the development of chemical industry exports, while it shows to be the second most important factor across all other countries. Second, the importance of 'pollution' as contributor to the predicted development of the dependent variable varies considerably across countries and across country clusters. Among poor pollution performers, 'pollution' contributes with +16 percent in average, which is the same average contribution as 'productivity', while in other country clusters, the relative importance of 'productivity' appears more accentuated.

The predicted contribution to the overall development of chemical industry exports in relative terms ranged from +20 percent in Spain, to -18 percent in Germany. Hence, pollution performance appeared to make a cumulative difference of 38 percent. This finding is indeed a strong indicator for the importance of relative pollution performance to chemical industry competitiveness.

Table 24 Actual and predicted changes: CI exports, absolute terms

Chemical Industry Intra-EU Exports, absolute terms, 1990-1998

Poor pollution performers	gr	es	pt	AVG
Actual Change	25%	114%	64%	**67%**
Predicted Change	104%	90%	131%	**108%**
contribution to the predicted change				
TAXES	-1%	-4%	-3%	**-3%**
FUEL PRICE	-1%	-3%	1%	**-1%**
PRODUCTIVITY	9%	20%	20%	**16%**
GDP	19%	0%	30%	**17%**
POLLUTION	7%	8%	6%	**7%**
(year)	71%	69%	76%	**72%**

Countries that catch up	ie	uk	AVG
Actual Change	335%	83%	**209%**
Predicted Change	154%	84%	**119%**
contribution to the predicted change			
TAXES	6%	-3%	**1%**
FUEL PRICE	1%	-2%	**0%**
PRODUCTIVITY	14%	10%	**12%**
GDP	49%	17%	**33%**
POLLUTION	3%	-5%	**-1%**
(year)	81%	67%	**74%**

Countries that fall behind	be	fr	fi	it	se	AVG
Actual Change	120%	89%	141%	83%	95%	**105%**
Predicted Change	87%	82%	76%	69%	103%	**84%**
contribution to the predicted change						
TAXES	-2%	-1%	1%	-11%	1%	**-2%**
FUEL PRICE	-1%	-2%	2%	-1%	6%	**1%**
PRODUCTIVITY	15%	14%	22%	20%	34%	**21%**
GDP	6%	2%	-19%	-7%	-12%	**-6%**
POLLUTION	1%	3%	4%	4%	3%	**3%**
(year)	68%	67%	66%	64%	71%	**67%**

Strong pollution performers	at	dk	de	nl	AVG
Actual Change	78%	147%	48%	42%	**79%**
Predicted Change	102%	82%	97%	84%	**91%**
contribution to the predicted change					
TAXES	-1%	-3%	0%	-4%	**-2%**
FUEL PRICE	1%	-9%	1%	-4%	**-3%**
PRODUCTIVITY	21%	19%	18%	13%	**18%**
GDP	10%	8%	17%	13%	**12%**
POLLUTION	0%	-1%	-9%	-1%	**-3%**
(year)	71%	67%	70%	67%	**69%**

Calculations based on regression model 24.1

Based on the coefficients that were estimated by model 21.1, table 24 compares the actual to the predicted changes with regard to absolute intra-EU chemical industry exports. As was the case with regard to chemical industry production as well, the observed actual changes in chemical industry exports were bigger in absolute terms than in relative terms. Considering that these relative numbers reveal the chemical industry performance in excess of the general economic performance, this observation seems in line with what would be expected.

Secondly, the contribution of 'pollution' appears, with regard to the development of chemical industry exports in absolute terms, smaller than in relative terms. This may be, on the one hand, explained by the before-mentioned "increased sensibility" of relative chemical industry export figures to environmental performance. Another possible explanation is the inclusion of the auxiliary independent variable 'GDP'.

Nevertheless, the importance of pollution performance is considerable, even when one looks at absolute export figures. Its predicted contribution to the overall development of chemical industry exports ranged from +8 percent in Spain, to -9 percent in Germany. Hence, pollution performance appeared to make a cumulative difference of no less than 17 percent.

Interim conclusion

The regression analysis on the link between intra-EU chemical industry exports and the independent variables clearly shows that pollution performance is one of the main determining factors. In general, 'pollution' is positively linked to chemical industry exports. For this reason, the results of this regression analysis seem to reject the null hypothesis and to lend support to hypothesis $H_{1.1}$, which states that chemical industry performance deteriorates in response to strong pollution performance. This is consistent with the findings of the regression analysis concerning chemical industry production value.

The size of the predicted contribution from pollution performance to chemical industry exports varies across countries, but appears in general remarkably high. Based on the findings of this regression analysis, the factor 'pollution' contributed a cumulative difference of 38 percent to the development of chemical industry exports in relative terms, and of 17 percent to absolute export figures. Hence, pollution performance seems to have a large impact on the chemical industry competitiveness, which is driving the sector's exports.

4.2.4 Summary of the empirical observations

Table 25 summarises the significant coefficients across the three dependent variables. 'Productivity' and 'pollution' were found to be the most important variables to explain the development of the chemical sector's performance. Both variables were found to be positively linked to production value and intra-EU exports. Taxes, on the other hand, were very significant and negative only with regard to chemical industry production value.

Table 25 Summary of regression results

	Taxes	**Fuel price**	**Productivity**	**Pollution performance**
Production value	- - -			+ + +
Employment			+	
Intra-EU exports			+ +	+ +

Note: Based on regression models 15.1, 19.1, and 21.1

+	Positive and significant at 10% significance level
++	Positive and significant at 5% significance level
+++	Positive and significant at 1% significance level
-	Negative and significant at 10% significance level
–	Negative and significant at 5% significance level
—	Negative and significant at 1% significance level

Looking at the tables that report the predicted contribution of each independent variable, there are at least two interesting observations. First, the cluster of poor pollution performers has suffered from increases in taxes over the observation period 1980 to 1999. Looking at the development of this independent variable over time (table 32), it seems reasonable to assume that this increase in taxes was related to the accession of Greece, Portugal and Spain to the European Community in the 1980s. On the other hand, the pollution load on these countries also increased over the period, from below-EU-average levels towards the average (and beyond, as table 29 shows). Hence, one could talk about a *double convergence*, in taxes and pollution, among these accession countries.

The net effect of this double convergence appears to be almost a zero-sum-game, as the predicted contributions in table 17 and table 18 illustrate.

Secondly, the predicted contribution of 'productivity' to all chemical industry performance variables appears to be larger among countries in the strong pollution performance cluster and the falling-behind pollution performance cluster (which could be considered the cluster of formerly strong pollution performers). Hence, the findings of the regression analysis could lend some support to the Porter hypothesis on innovation offsets.

5 The scope of environmental competition: some conclusions from this study

5.1 *Summary of the main findings*

This thesis was about environmental competition. The research problem at the heart of the analysis was the question whether countries compete among themselves by the means of 'playing' with their environmental performance in order to foster industrial activity. On the balance of the empirical results, the preliminary answer is yes – with some qualifications attached.

In order to reach this conclusion, the first step was to construct a proxy indicator for environmental performance. There are several approaches to deal with environmental performance in social sciences. Since one of the initial objectives of this research was to carry out a quantitative comparative analysis, the approach of choice was pollution performance analysis. Pollution performance is too broad a concept to be workable in practice, so this study had to narrow the concept of pollution performance to air pollution performance. Therefore, the basis of the indicator was an average of several air pollutants.

Since the frame of reference for this thesis was a closed system (the EU 15), the air pollution time series were transformed into a relative performance indicator across the countries within the system. The advantage of this approach is that it is comparative in nature – once the indicator is developed, one can easily work out distinct pollution performance patterns, rank countries according to their pollution performance, or classify them into performance clusters.

Therefore, using the air pollution indicator, the first contribution of this thesis, is the classification of EU 15 member states according to their empirically observed pollution performance during the period 1990 to 1999. The classification produced four distinct clusters. There were two "clear-cut" performance clusters with countries that were either clearly poor pollution performers or strong pollution performers. Countries in the first cluster were Greece, Portugal and Spain. They exhibited poor initial performance levels with respect to the EU average and a lack of convergence. Inversely, strong pollution performers, such as Austria, Denmark, Germany and the Netherlands were characterised by strong initial pollution levels with regard to the other countries, and also a lack of convergence. Furthermore, there were two 'transitory' pollution performance clusters. The first of those two clusters comprises countries in the process of catching-up: its constituents start from relatively poor pollution performance levels, but show convergence towards the EU average. This group is comprised of Ireland, Luxembourg and the United Kingdom. The last cluster contains countries that fall behind in terms of pollution performance, such as Belgium, Finland, France, Italy, and Sweden. These countries show strong initial pollution performance levels, but converge downwards towards (and in some cases, beyond) the EU average.

The second part of the thesis evolved around the idea to relate the pollution performance indicator to a number of variables that capture the performance of chemical industries using panel data of 15 EU countries along 20 years. The main hypothesis to be tested was whether strong pollution performance had an impact on chemical industry performance, and if so, what the sign of that relationship was. There were three performance variables: production value, employment, and value of intra-EU exports – in order to stay within the EU as frame of reference.

The results of the regression analysis show that, with regard to two of the three chemical industry performance variables, strong pollution performance has a negative and significant impact. This is the case with regard to production value and intra-EU exports. This finding is in line with conventional economic and location theory, which states that there is a trade-off between economic performance and environmental performance. The empirical observations of this thesis lend further support to such theories. Hence, it seems that the countries in the sample actually do compete by means of environmental competition.

On the other hand, this study did not produce evidence that strong pollution performance has had an impact on the employment of the chemical industries in the EU. Hence, employment seems to respond to a different set of factors.

Besides the pollution performance indicator, this study produced a number of interesting results on the effect of other explanatory variables on the evolution of chemical industries. First, the contribution of manufacturing productivity to both chemical industry production value and exports was remarkably large within the strong pollution performance cluster as well as to the falling-behind country cluster. Moreover, manufacturing productivity was shown to be the only significant and positive explanatory variable in the employment regression.

Second, taxes on production and imports had a negative impact on chemical industry production value. The contribution of this explanatory factor was especially significant within the poor pollution performer cluster, which is comprised of Greece, Portugal and Spain. It seems that all three countries experienced a "double convergence" during their accession process to the European Community during the 1980s. On the one hand, the three countries had to adjust their tax level upwards to meet EC standards, which harmed their chemical industries' production. On the other hand, pollution performance also converged from low initial levels towards European averages (and beyond), which had a positive impact on chemical industry production levels. According to the results of the regression analysis, the overall outcome of this double convergence was, more or less, a zero-sum-game.

5.2 *Directions for future research*

One of the hottest issues in the news concerns the relocation of industries to the newly acceded EU countries. Given the fact that, due to data constraints, this study only covered the EU-15 member states, one obvious field for future research would be to include all EU-26 countries, or to include further transition economies. In particular, it would be very interesting to see whether these countries also experience what was called a double convergence. Or, in other words, are these countries currently attempting to compete – among others – on the basis of their environmental performance?

Another promising field for future research seems to originate from one of the by-products of this study, which is the observation that countries in the strong pollution performer cluster and the falling-behind pollution performance cluster (that is, in a sense, the cluster of formerly strong pollution performers), benefit consistently from higher contributions of the 'productivity' variable to chemical industry performance. This could suggest that the returns from investing in strong pollution performance are achieved and harvested in the long term.

The explanatory variables used in the regression analysis did not explain the employment performance of chemical industries. Hence, one interesting research question could be to identify the 'missing link', that is the determinants of employment in such a special industry.

Last but not least, another promising research question could be to expand the frame of reference beyond the European Union, with the United Sates or Japan as the obvious candidates for inclusion.

5.3 Cost and benefits of environmental protection: some policy implications from this study

To conclude this investigation, let us take a step back and assess its implications 'in the big picture' in terms of policies, business strategies, and further academic research. Obviously, one needs to be very cautious to point out once more that there are important constraints that should prevent the reader from taking its results as generally valid. First, this study was set-up as a case study, which uses the 15 EU member states as a closed frame of reference. Second, it used air pollution performance as a proxy for environmental competition. Third, the analysis is limited to the period of 1980 to 1999. Given the broadness and complexity of the academic arenas that link into the notion of environmental competition, the narrow scope of this investigation will obviously limit the degree to which it could be taken as generally applicable.

Fourth, and maybe most importantly, in order to keep the analysis within a manageable scope, we had to focus on testing one specific set of hypotheses. Although there is a range of what one might consider interesting 'collateral' findings, this thesis can merely point at the apparent existence of those additional findings and recommend further investigation. However, if we allow ourselves to relax this strict standard of objectivity for a moment and permit some degree of 'educated' speculation, an intriguing set of policy implications emerges.

A puzzle of three pieces

This investigation has produced three sets of observations on how relative air pollution performance among EU member states may have shaped the competitiveness of their chemical industries. The first set of insights highlights the correlation between air pollution performance and chemical industry competitiveness indicators. The second set of observations highlights the predicted contribution from the factors 'pollution performance' and 'taxes' on chemical industry competitiveness, and how the observed differences vary among the four pollution performance clusters. Finally, the third set of observations focuses on the differences in the contribution of the independent variable 'productivity' among the four pollution performance clusters. Like a puzzle, taken together these three sets of insights seem to fit into one consistent overall picture.

Trading-off air pollution performance for chemical industry competitiveness does work

The first insight of this investigation is the notion that there seems to be a trade-off between chemical industry production value as well as market share on the one hand, and air pollution performance on the other hand. Furthermore, this investigation showed no apparent link between pollution performance and chemical industry employment levels.

The policy implications from this set of observations seem to be straight forward: governments have certain scope for environmental competition. In other words, there seems to be the possibility to trade pollution performance for chemical industry production value and market share. The possibility of trading pollution performance for jobs in the chemical industry sector seems much less certain. Hence, this investigation lends some support to the notions of environmental externalities and of the environmental Kuznets curve.

At this point, one should recall that the regression models did not use time lags between dependent and independent variables. Hence, the trade-off between pollution performance and chemical industry competitiveness appears to occur in a relatively short term. From a policy point of view, this may be an important consideration: the results of this research seem to point at the opportunity to realize relatively quick economic gains through the reduction of environmental performance. Therefore, if governments are pressed to generate economic wealth within a limited period of time, pursuing a strategy of "selling off" pollution performance, may appear an appealing option. The medium and long term implications of such a strategy are, however, not covered by this first set of insights, but rather by the subsequent two.

Double convergence: avoid trading-off pollution performance for the adjustment of tax levels among accession countries

The second insight of this investigation is related to what has been called the phenomenon of "double convergence". Based on the predicted contributions to chemical industry competitiveness by the factors 'pollution' and 'taxes', one could conclude that the chemical industries of Greece, Portugal and Spain have at the same time profited and suffered from the accession to the EU and its common market. On the one hand, the three countries appear to have succeeded in trading some of their pollution performance for chemical industry competitiveness within the European market. On the other hand, it seems that at the same time, while converging to European standards, the tax regimes of those countries changed to the disadvantage of chemical industries. In the end, competitiveness gains due to weak environmental performance were to a large degree compensated by changes in the tax regime.

This notion could be relevant with regard to how to manage the accession of further countries to the European Union. If we accept the notion of a "double convergence", one might speculate whether limiting the rate of upward adjustment of tax levels in the accession countries could actually reduce the pressure on national governments to trade-off pollution performance in order to compensate for the implied loss of chemical industry competitiveness.

Productivity increases through environmental innovation offsets: the jury is still out

The third insight of this investigation concerns the indirect impact of pollution performance on productivity levels. Due to the focus of this study, the results do not present any definite endorsement or negation to the Porter hypothesis, which claims that strong environmental regulation induces innovation offsets, which, in the medium and long run would increase productivity levels. Yet, at the least, our empirical data seems to show circumstantial evidence that the Porter Hypothesis could hold. If so, policy implications would be important.

First of all, it would open the possibility for governments to justify a policy of pollution performance leadership by pointing at the long term economic benefits. The biggest advantage of such a policy would be its sustainability, not only in the environmental sense but more importantly in the economic sense, as higher levels of innovation and productivity are genuine competitive advantages, which are difficult for competitors to match. In comparison, although selling-off pollution performance for short-term increases in wealth is possible in the short-run, such policies do not create genuine competitive advantages, since relaxing pollution performance levels is a strategy that can be matched by any competitor.

The second important policy implication concerns the design of environmental regulation. If innovation offsets originate from pollution policies, governments need to design regulations that enable the creation and spread of innovations across industrial sectors. In this context, policies aimed at the chemical industry would be key, as this sector is generally seen as a generator and multiplier of environmental innovation across a range of connected industries. Therefore, governments should seek to design policies that encourage the development of pollution-reducing technologies within the chemical industry, as well as the multiplication of such technologies across connected industrial sectors. For this reason, environmental policies that aim to enable the Porter Hypothesis to hold should not only consist of setting strict pollution standards, but also of supporting measures such as subsidising R&D, protecting intellectual property, as well as facilitating the exchange of knowledge across industry networks or local knowledge clusters.

Appendices

Appendix 1: Pollution performance indicators

Table 26 Anthropogenic emissions per capita

Anthropogenic CH_4 emissions (g / cap.)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be											0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.058	0.058	0.057
dk	0.064	0.065	0.065	0.064	0.064	0.062	0.061	0.059	0.058	0.059	0.054	0.055	0.054	0.055	0.054	0.054	0.053	0.051	0.054	0.051
de	0.080	0.078	0.076	0.075	0.074	0.076	0.075	0.073	0.071	0.070	0.070	0.063	0.058	0.053	0.049	0.048	0.044	0.042	0.041	0.040
gr											0.043	0.043	0.043	0.042	0.043	0.044	0.043	0.044	0.044	0.044
es	0.030	0.030	0.033	0.033	0.034	0.034	0.037	0.039	0.039	0.042	0.042	0.042	0.043	0.044	0.045	0.046	0.048	0.049	0.050	0.051
fr											0.052	0.053	0.052	0.053	0.053	0.053	0.052	0.048	0.047	0.045
ie											0.172	0.172	0.172	0.172	0.173	0.174	0.174	0.175	0.172	0.170
it	0.039	0.038	0.038	0.039	0.039	0.039	0.040	0.040	0.041	0.040	0.041	0.041	0.041	0.042	0.044	0.044	0.033	0.033	0.033	0.033
lu											0.063	0.059	0.059	0.063	0.054	0.056	0.058	0.057	0.054	0.055
nl	0.069	0.061	0.061	0.070	0.072	0.081	0.072	0.071	0.069	0.070	0.087	0.086	0.083	0.080	0.078	0.076	0.079	0.071	0.068	0.065
at	0.070	0.070	0.070	0.071	0.071	0.071	0.071	0.071	0.070	0.070	0.070	0.067	0.065	0.064	0.062	0.061	0.060	0.058	0.057	0.056
pt											0.064	0.065	0.064	0.063	0.064	0.064	0.064	0.064	0.064	0.063
fi											0.060	0.056	0.050	0.045	0.044	0.044	0.042	0.040	0.038	0.037
se											0.038	0.038	0.037	0.037	0.035	0.034	0.034	0.029	0.029	0.034
uk	0.069	0.069	0.070	0.070	0.057	0.066	0.069	0.068	0.067	0.065	0.064	0.063	0.061	0.055	0.050	0.050	0.049	0.047	0.045	0.047
AVG											**0.065**	**0.064**	**0.063**	**0.062**	**0.060**	**0.060**	**0.059**	**0.058**	**0.057**	**0.057**
COV											**0.12**	**0.13**	**0.13**	**0.13**	**0.14**	**0.14**	**0.14**	**0.15**	**0.15**	**0.14**

Note: AVG **Weighted average (weights according to the ratio national vs. total population)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt: 2000)
CO_2 emission data from CDIAC (2002)
Population data from Eurostat (2001)

Anthropogenic CO_2 emissions (g / cap.)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	3.64	3.36	3.20	2.76	2.83	2.82	2.72	2.70	2.47	2.65	2.75	2.87	2.82	2.70	2.79	2.85	2.90	2.79	2.71	2.80
dk	3.35	2.90	2.98	2.79	2.83	3.37	3.29	3.26	2.92	2.53	2.69	3.33	2.87	2.99	3.20	2.91	3.76	3.04	2.75	3.15
de	3.38	3.15	3.00	2.99	3.06	3.04	3.03	2.97	2.97	2.89	2.32	3.04	2.92	2.85	2.93	2.77	2.87	2.77	2.74	2.88
gr	1.46	1.42	1.45	1.54	1.57	1.65	1.61	1.71	1.81	1.97	1.94	1.78	1.95	1.94	2.01	2.02	2.15	2.14	2.21	2.23
es	1.46	1.44	1.44	1.40	1.30	1.35	1.23	1.26	1.29	1.47	1.49	1.51	1.57	1.44	1.51	1.62	1.62	1.70	1.71	1.72
fr	2.44	2.19	2.09	1.98	1.90	1.86	1.77	1.68	1.65	1.72	1.72	1.84	1.73	1.68	1.55	1.64	1.74	1.60	1.72	1.85
ie	2.02	2.00	1.97	1.93	1.93	1.98	2.21	2.31	2.34	2.22	2.32	2.58	2.42	2.43	2.53	2.53	2.64	2.72	2.81	2.76
it	1.80	1.76	1.71	1.64	1.68	1.71	1.66	1.73	1.76	1.85	1.89	1.90	1.92	1.84	1.82	1.92	1.88	1.90	1.93	1.90
lu	7.91	6.74	6.34	5.93	6.36	6.48	6.36	6.11	6.31	6.69	7.07	7.47	7.48	7.40	6.89	5.54	5.53	5.12	4.91	4.66
nl	2.95	2.76	2.14	2.22	2.39	2.55	2.43	2.48	2.39	2.72	2.74	2.73	2.67	2.77	2.55	2.69	2.98	2.84	2.85	2.87
at	1.89	2.03	1.94	1.87	1.94	1.95	1.92	1.94	1.86	1.89	2.03	2.11	1.95	1.92	1.94	1.96	2.01	2.06	2.16	2.08
pt	0.75	0.70	0.80	0.82	0.78	0.83	0.81	0.87	0.89	1.12	1.17	1.17	1.30	1.26	1.29	1.39	1.32	1.38	1.50	1.48
fi	3.25	2.84	2.59	2.35	2.26	2.67	3.05	3.00	2.80	2.91	2.90	2.84	2.60	2.67	2.89	2.80	3.25	3.10	2.82	3.04
se	2.34	2.24	1.99	1.85	1.80	1.97	1.94	1.87	1.85	1.76	1.55	1.60	1.62	1.50	1.56	1.44	1.67	1.47	1.50	1.51
uk	2.81	2.67	2.66	2.65	2.51	2.65	2.69	2.71	2.69	2.72	2.70	2.75	2.59	2.56	2.54	2.52	2.63	2.49	2.50	2.46
AVG	**2.76**	**2.55**	**2.42**	**2.31**	**2.34**	**2.46**	**2.45**	**2.44**	**2.40**	**2.47**	**2.49**	**2.63**	**2.56**	**2.53**	**2.53**	**2.44**	**2.60**	**2.47**	**2.45**	**2.49**
COV	**0.15**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.14**	**0.14**	**0.14**	**0.14**	**0.13**	**0.10**	**0.10**	**0.09**	**0.09**	**0.08**

Note: **AVG** **Weighted average (weights according to the ratio national vs. total population)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt: 2000)
CO_2 emission data from CDIAC (2002)
Population data from Eurostat (2001)

Anthropogenic SO_2 emissions (g / cap.)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	0.084	0.072	0.070	0.057	0.051	0.040	0.038	0.037	0.036	0.033	0.037	0.033	0.032	0.029	0.025	0.024	0.024	0.022	0.021	0.018
dk	0.088	0.072	0.074	0.063	0.060	0.067	0.057	0.050	0.050	0.039	0.036	0.047	0.036	0.030	0.030	0.028	0.034	0.021	0.015	0.011
de	0.051	0.049	0.046	0.043	0.042	0.039	0.036	0.031	0.020	0.015	0.067	0.050	0.041	0.036	0.030	0.024	0.017	0.014	0.011	0.010
gr	0.041	0.043	0.045	0.047	0.048	0.050	0.050	0.050	0.050	0.050	0.050	0.054	0.054	0.053	0.050	0.053	0.052	0.051	0.051	0.051
es	0.076	0.073	0.072	0.073	0.066	0.062	0.059	0.055	0.046	0.055	0.053	0.053	0.052	0.049	0.048	0.044	0.038	0.039	0.037	0.035
fr	0.060	0.047	0.044	0.036	0.032	0.027	0.024	0.024	0.022	0.024	0.023	0.024	0.021	0.018	0.017	0.016	0.016	0.013	0.014	0.012
ie	0.065	0.056	0.045	0.041	0.040	0.040	0.046	0.049	0.043	0.046	0.053	0.051	0.048	0.045	0.049	0.045	0.040	0.045	0.047	0.042
it	0.067	0.059	0.050	0.043	0.037	0.033	0.034	0.035	0.034	0.032	0.029	0.027	0.024	0.023	0.022	0.023	0.021	0.018	0.018	0.016
lu	0.066	0.057	0.047	0.038	0.041	0.044	0.043	0.042	0.041	0.040	0.039	0.039	0.038	0.038	0.032	0.022	0.019	0.014	0.009	0.009
nl	0.035	0.033	0.028	0.022	0.021	0.018	0.018	0.018	0.017	0.014	0.014	0.011	0.011	0.011	0.009	0.010	0.009	0.008	0.007	0.006
at	0.051	0.044	0.042	0.031	0.028	0.025	0.023	0.020	0.015	0.013	0.012	0.011	0.008	0.008	0.007	0.007	0.007	0.006	0.006	0.005
pt	0.027	0.028	0.029	0.031	0.025	0.020	0.023	0.022	0.020	0.028	0.036	0.035	0.041	0.036	0.034	0.037	0.033	0.034	0.038	0.035
fi	0.122	0.111	0.100	0.077	0.075	0.078	0.067	0.067	0.061	0.049	0.052	0.039	0.028	0.024	0.022	0.019	0.020	0.019	0.017	0.017
se	0.059	0.052	0.045	0.037	0.036	0.032	0.032	0.027	0.027	0.019	0.014	0.011	0.010	0.010	0.009	0.009	0.009	0.006	0.006	0.007
uk	0.087	0.079	0.075	0.069	0.066	0.066	0.069	0.069	0.067	0.065	0.065	0.062	0.059	0.053	0.046	0.040	0.034	0.028	0.026	0.020
AVG	**0.065**	**0.058**	**0.054**	**0.047**	**0.045**	**0.043**	**0.041**	**0.040**	**0.037**	**0.035**	**0.039**	**0.036**	**0.034**	**0.031**	**0.029**	**0.027**	**0.025**	**0.022**	**0.021**	**0.020**
COV	**0.09**	**0.09**	**0.09**	**0.08**	**0.09**	**0.11**	**0.10**	**0.10**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.12**	**0.12**	**0.13**	**0.13**	**0.15**	**0.16**	**0.16**

Note: **AVG** **Weighted average (weights according to the ratio national vs. total population)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt: 2000)
CO_2 emission data from CDIAC (2002)
Population data from Eurostat (2001)

Anthropogenic NO_2 emissions (g / cap.)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	0.045	0.043	0.040	0.038	0.035	0.033	0.032	0.034	0.035	0.036	0.034	0.033	0.034	0.034	0.034	0.033	0.031	0.030	0.031	0.029
dk	0.053	0.047	0.052	0.050	0.053	0.057	0.063	0.059	0.058	0.054	0.053	0.061	0.052	0.051	0.052	0.048	0.055	0.047	0.044	0.040
de	0.043	0.041	0.041	0.042	0.042	0.042	0.042	0.040	0.038	0.035	0.034	0.031	0.029	0.027	0.025	0.024	0.023	0.022	0.021	0.020
gr	0.030	0.030	0.030	0.030	0.031	0.031	0.031	0.032	0.033	0.033	0.032	0.032	0.032	0.032	0.033	0.033	0.036	0.034	0.036	0.036
es	0.027	0.025	0.025	0.025	0.025	0.024	0.025	0.026	0.027	0.029	0.030	0.031	0.032	0.031	0.031	0.031	0.030	0.032	0.033	0.033
fr	0.037	0.035	0.034	0.034	0.033	0.033	0.032	0.032	0.032	0.033	0.033	0.034	0.033	0.031	0.030	0.029	0.029	0.028	0.027	0.026
ie	0.021	0.025	0.025	0.024	0.024	0.026	0.028	0.032	0.035	0.036	0.034	0.034	0.037	0.033	0.032	0.032	0.033	0.032	0.033	0.032
it	0.029	0.028	0.028	0.028	0.028	0.028	0.030	0.032	0.032	0.033	0.034	0.034	0.035	0.034	0.031	0.030	0.030	0.028	0.027	0.025
lu	0.063	0.062	0.060	0.057	0.057	0.057	0.058	0.059	0.060	0.061	0.060	0.061	0.063	0.063	0.057	0.051	0.053	0.043	0.040	0.037
nl	0.041	0.040	0.039	0.039	0.040	0.041	0.040	0.041	0.041	0.039	0.039	0.038	0.037	0.035	0.033	0.032	0.032	0.029	0.027	0.026
at	0.030	0.029	0.029	0.028	0.028	0.029	0.028	0.028	0.027	0.025	0.025	0.025	0.024	0.022	0.023	0.021	0.021	0.021	0.021	0.021
pt	0.017	0.017	0.018	0.019	0.014	0.010	0.011	0.012	0.012	0.013	0.032	0.034	0.036	0.035	0.035	0.036	0.036	0.036	0.037	0.038
fi	0.062	0.058	0.056	0.054	0.053	0.056	0.056	0.058	0.059	0.061	0.060	0.058	0.056	0.056	0.055	0.051	0.052	0.051	0.049	0.048
se	0.049	0.050	0.049	0.048	0.049	0.051	0.052	0.052	0.051	0.049	0.039	0.039	0.038	0.037	0.038	0.034	0.034	0.031	0.029	0.029
uk	0.046	0.044	0.044	0.044	0.043	0.045	0.046	0.048	0.049	0.049	0.048	0.046	0.044	0.041	0.039	0.036	0.034	0.031	0.029	0.027
AVG	**0.040**	**0.038**	**0.038**	**0.037**	**0.037**	**0.037**	**0.038**	**0.039**	**0.039**	**0.039**	**0.039**	**0.039**	**0.039**	**0.037**	**0.036**	**0.035**	**0.035**	**0.033**	**0.032**	**0.031**
COV	**0.09**	**0.08**	**0.08**	**0.08**	**0.08**	**0.09**	**0.09**	**0.09**	**0.09**	**0.08**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.06**	**0.07**	**0.06**	**0.06**	**0.06**

Note: **AVG** **Weighted average (weights according to the ratio national vs. total population)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt: 2000)
CO_2 emission data from CDIAC (2002)
Population data from Eurostat (2001)

Anthropogenic NMVOC emissions (g / cap.)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be						0.070	0.060	0.054	0.048	0.041	0.036	0.031	0.031	0.031	0.030	0.029	0.027	0.027	0.027	0.027
dk	0.040	0.039	0.039	0.039	0.040	0.038	0.039	0.039	0.038	0.038	0.033	0.032	0.031	0.031	0.029	0.028	0.028	0.026	0.025	0.024
de	0.041	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.039	0.037	0.041	0.035	0.032	0.029	0.027	0.025	0.023	0.022	0.021	0.020
gr						0.062	0.057	0.052	0.047	0.042	0.033	0.033	0.033	0.034	0.034	0.035	0.036	0.037	0.038	0.038
es	0.069	0.067	0.066	0.067	0.067	0.068	0.068	0.069	0.070	0.071	0.072	0.070	0.068	0.064	0.069	0.067	0.064	0.068	0.068	0.068
fr											0.043	0.043	0.042	0.039	0.037	0.035	0.034	0.033	0.032	0.030
ie											0.031	0.031	0.032	0.030	0.030	0.029	0.030	0.031	0.031	0.025
it	0.039	0.037	0.037	0.036	0.035	0.035	0.035	0.036	0.037	0.038	0.038	0.040	0.040	0.040	0.040	0.041	0.033	0.032	0.030	0.028
lu						0.041	0.043	0.045	0.047	0.048	0.050	0.048	0.047	0.045	0.045	0.039	0.038	0.036	0.030	0.035
nl						0.035	0.034	0.033	0.036	0.032	0.034	0.031	0.029	0.026	0.025	0.024	0.023	0.020	0.019	0.018
at	0.047	0.047	0.046	0.047	0.048	0.047	0.049	0.049	0.050	0.048	0.045	0.040	0.035	0.034	0.032	0.032	0.031	0.030	0.029	0.029
pt						0.020	0.023	0.027	0.031	0.035	0.038	0.041	0.044	0.045	0.045	0.047	0.044	0.050	0.049	0.050
fi								0.043	0.043	0.044	0.042	0.041	0.040	0.038	0.037	0.036	0.034	0.034	0.033	0.032
se									0.066	0.064	0.061	0.060	0.056	0.055	0.054	0.052	0.052	0.047	0.047	0.047
uk	0.042	0.042	0.042	0.043	0.044	0.044	0.045	0.046	0.047	0.047	0.046	0.045	0.043	0.041	0.040	0.038	0.037	0.035	0.032	0.029
AVG											**0.043**	**0.041**	**0.040**	**0.039**	**0.038**	**0.037**	**0.036**	**0.035**	**0.034**	**0.033**
COV											**0.07**	**0.07**	**0.07**	**0.07**	**0.08**	**0.08**	**0.08**	**0.09**	**0.09**	**0.10**

Note: **AVG** **Weighted average (weights according to the ratio national vs. total population)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt: 2000)
CO_2 emission data from CDIAC (2002)
Population data from Eurostat (2001)

Anthropogenic CO emissions (g / cap.)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be											0.112	0.112	0.113	0.109	0.104	0.102	0.099	0.093	0.095	0.092
dk	0.187	0.210	0.219	0.186	0.207	0.194	0.195	0.199	0.183	0.195	0.137	0.139	0.133	0.128	0.119	0.116	0.119	0.107	0.113	0.102
de	0.179	0.163	0.154	0.149	0.151	0.147	0.146	0.141	0.135	0.127	0.142	0.119	0.104	0.095	0.087	0.082	0.076	0.071	0.065	0.060
gr											0.131	0.134	0.128	0.127	0.126	0.128	0.132	0.134	0.142	0.136
es	0.098	0.094	0.092	0.093	0.092	0.090	0.091	0.094	0.099	0.103	0.100	0.103	0.105	0.099	0.099	0.088	0.093	0.099	0.099	0.100
fr	0.292	0.276	0.266	0.257	0.257	0.252	0.243	0.238	0.229	0.218	0.190	0.187	0.178	0.167	0.155	0.152	0.142	0.134	0.129	0.121
ie											0.114	0.112	0.111	0.098	0.092	0.085	0.084	0.085	0.086	0.076
it	0.134	0.132	0.133	0.131	0.133	0.135	0.133	0.134	0.132	0.134	0.136	0.138	0.138	0.133	0.130	0.133	0.119	0.114	0.108	0.103
lu											0.458	0.587	0.520	0.550	0.359	0.261	0.248	0.190	0.120	0.115
nl						0.095	0.086	0.081	0.080	0.076	0.076	0.068	0.065	0.063	0.059	0.058	0.058	0.048	0.046	0.043
at	0.227	0.217	0.209	0.205	0.212	0.204	0.217	0.211	0.204	0.194	0.169	0.165	0.152	0.147	0.143	0.130	0.127	0.127	0.120	0.107
pt											0.113	0.120	0.130	0.128	0.125	0.121	0.119	0.115	0.110	0.115
fi											0.112	0.110	0.095	0.090	0.087	0.085	0.090	0.092	0.088	0.106
se											0.141	0.141	0.136	0.132	0.130	0.123	0.122	0.109	0.113	0.104
uk	0.136	0.135	0.135	0.131	0.131	0.127	0.127	0.127	0.128	0.131	0.124	0.120	0.114	0.106	0.100	0.094	0.093	0.088	0.084	0.080
AVG											**0.150**	**0.157**	**0.148**	**0.145**	**0.128**	**0.117**	**0.115**	**0.107**	**0.101**	**0.097**
COV											**0.15**	**0.19**	**0.18**	**0.20**	**0.13**	**0.10**	**0.09**	**0.08**	**0.06**	**0.06**

Note: **AVG** **Weighted average (weights according to the ratio national vs. total population)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt: 2000)
CO_2 emission data from CDIAC (2002)
Population data from Eurostat (2001)

Anthropogenic NH_3 emissions (g / cap.)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be						0.0090	0.0094	0.0097	0.0101	0.0104	0.0107	0.0093	0.0092	0.0096	0.0095	0.0096	0.0097	0.0097	0.0100	0.0101
dk	0.0244	0.0240	0.0234	0.0233	0.0225	0.0264	0.0264	0.0256	0.0249	0.0250	0.0249	0.0240	0.0233	0.0225	0.0216	0.0201	0.0191	0.0189	0.0190	0.0181
de	0.0093	0.0090	0.0092	0.0094	0.0096	0.0096	0.0095	0.0094	0.0091	0.0090	0.0097	0.0084	0.0081	0.0079	0.0078	0.0078	0.0078	0.0076	0.0077	0.0076
gr											0.0078	0.0076	0.0073	0.0072	0.0070	0.0081	0.0070	0.0068	0.0070	0.0069
es	0.0106	0.0101	0.0108	0.0108	0.0109	0.0109	0.0113	0.0123	0.0123	0.0126	0.0121	0.0120	0.0120	0.0115	0.0120	0.0119	0.0132	0.0128	0.0130	0.0131
fr											0.0139	0.0138	0.0135	0.0133	0.0134	0.0134	0.0136	0.0137	0.0137	0.0136
ie											0.0319	0.0326	0.0330	0.0328	0.0333	0.0335	0.0336	0.0335	0.0342	0.0338
it	0.0085	0.0084	0.0082	0.0089	0.0084	0.0085	0.0086	0.0087	0.0087	0.0084	0.0081	0.0078	0.0076	0.0077	0.0079	0.0079	0.0074	0.0076	0.0075	0.0076
lu											0.0183	0.0181	0.0178	0.0176	0.0173	0.0171	0.0168	0.0166	0.0164	0.0169
nl	0.0165	0.0168	0.0170	0.0170	0.0171	0.0171	0.0177	0.0176	0.0161	0.0156	0.0151	0.0151	0.0119	0.0125	0.0108	0.0094	0.0094	0.0120	0.0108	0.0111
at	0.0104	0.0105	0.0105	0.0107	0.0108	0.0107	0.0107	0.0106	0.0104	0.0104	0.0103	0.0101	0.0097	0.0095	0.0095	0.0092	0.0090	0.0089	0.0089	0.0087
pt											0.0106	0.0101	0.0108	0.0100	0.0094	0.0103	0.0100	0.0101	0.0103	0.0100
fi											0.0076	0.0079	0.0081	0.0077	0.0073	0.0069	0.0068	0.0074	0.0073	0.0068
se									0.0064	0.0062	0.0060	0.0059	0.0070	0.0070	0.0069	0.0069	0.0069	0.0067	0.0067	0.0062
uk											0.0063	0.0062	0.0059	0.0059	0.0059	0.0058	0.0057	0.0058	0.0059	0.0059
AVG											**0.0129**	**0.0126**	**0.0123**	**0.0122**	**0.0120**	**0.0119**	**0.0117**	**0.0119**	**0.0119**	**0.0118**
COV											**0.14**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**

Note: **AVG** **Weighted average (weights according to the ratio national vs. total population)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt: 2000)
CO_2 emission data from CDIAC (2002)
Population data from Eurostat (2001)

Table 27 Anthropogenic emissions / GDP

Anthropogenic CH_4 emissions / GDP (tonnes / million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be											3.839	3.652	3.413	3.248	3.023	2.815	2.783	2.712	2.609	2.480
dk	7.050	6.673	6.085	5.423	4.931	4.341	3.903	3.559	3.405	3.300	2.854	2.782	2.640	2.560	2.352	2.153	2.041	1.922	1.935	1.729
de	8.408	7.841	7.010	6.230	5.759	5.592	5.034	4.603	4.272	3.989	4.669	3.567	3.035	2.607	2.331	2.129	1.949	1.897	1.772	1.677
gr											6.659	6.032	5.716	5.567	5.309	5.093	4.630	4.292	4.291	3.918
es	7.290	6.937	6.816	7.231	6.438	6.021	5.912	5.804	5.108	4.573	4.114	3.789	3.721	4.105	4.257	4.114	4.055	4.050	3.944	3.810
fr											3.145	3.106	2.974	2.891	2.758	2.664	2.544	2.296	2.179	2.027
ie											18.907	18.017	16.823	16.659	15.306	14.295	12.996	11.276	10.370	9.325
it	6.699	5.977	5.287	4.806	4.244	4.015	3.731	3.542	3.329	2.979	2.756	2.607	2.553	2.974	3.041	3.117	2.037	1.959	1.893	1.817
lu											2.291	1.977	1.889	1.897	1.536	1.518	1.542	1.513	1.349	1.321
nl	7.875	6.815	6.157	6.616	6.488	6.946	5.761	5.558	5.274	5.014	5.818	5.553	5.076	4.597	4.251	3.860	3.933	3.435	3.119	2.891
at	9.427	8.769	7.697	6.959	6.592	6.189	5.661	5.270	5.018	4.692	4.298	3.936	3.572	3.273	3.037	2.780	2.686	2.585	2.421	2.291
pt											11.844	10.195	8.734	8.736	8.594	7.933	7.498	7.199	6.705	6.227
fi											2.885	2.942	3.202	3.340	2.808	2.398	2.265	2.025	1.812	1.644
se											1.847	1.729	1.741	2.110	1.886	1.750	1.566	1.346	1.311	1.489
uk	10.113	8.478	7.897	7.596	5.842	6.202	6.879	6.493	5.567	5.058	4.884	4.505	4.389	3.972	3.447	3.464	3.139	2.424	2.164	2.239
AVG											**5.387**	**4.959**	**4.632**	**4.569**	**4.262**	**4.006**	**3.711**	**3.395**	**3.192**	**2.992**
COV											**0.21**	**0.21**	**0.20**	**0.20**	**0.21**	**0.20**	**0.20**	**0.19**	**0.19**	**0.18**

Note: **AVG** **Weighted average (weights according to the ratio national vs. total GDP)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt 2000)
CO_2 emission data from CDIAC (2002)
GDP data from Eurostat (2001)

Anthropogenic CO_2 emissions / GDP (tonnes / million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	415.3	374.7	359.3	298.3	283.3	261.3	233.3	217.4	187.6	185.1	178.6	176.5	163.5	147.9	142.9	136.5	137.3	130.7	121.7	121.2
dk	368.8	297.6	278.9	235.0	218.0	234.7	209.5	196.3	169.9	141.8	141.8	169.7	139.5	139.3	139.1	116.8	144.8	113.6	98.4	107.6
de	355.8	317.0	275.9	249.0	237.5	224.9	203.4	187.3	179.8	165.4	154.3	172.9	153.7	141.2	138.1	123.9	128.2	124.2	119.0	121.3
gr	390.9	336.8	295.4	318.5	301.8	316.9	338.2	359.0	333.6	327.2	299.7	249.9	261.5	253.9	250.0	236.1	230.1	210.4	214.6	199.2
es	358.8	329.7	298.8	303.2	248.5	237.8	196.5	187.1	167.8	161.2	146.4	135.4	135.4	135.0	143.9	145.7	136.4	140.4	134.9	128.0
fr	274.1	225.9	202.2	183.7	165.3	149.7	132.6	122.4	113.8	110.9	104.2	108.9	97.9	92.0	81.2	81.9	84.4	76.8	79.0	82.5
ie	515.8	437.6	378.8	356.5	335.5	316.4	328.6	334.1	314.9	269.8	255.3	269.2	236.5	235.7	224.3	207.8	196.4	175.0	170.0	151.7
it	312.5	274.2	237.7	201.1	183.9	175.5	155.7	151.9	143.9	136.2	128.2	119.7	120.1	129.2	125.7	136.4	116.7	111.3	109.3	103.7
lu	727.0	570.5	472.9	399.2	391.4	353.7	320.1	296.6	285.8	271.0	257.9	250.7	241.0	223.6	194.3	149.7	147.8	135.8	122.9	112.0
nl	338.6	306.1	214.8	209.4	215.5	218.1	194.1	193.0	181.8	194.6	184.2	175.6	164.3	159.1	138.7	136.9	147.6	136.9	131.6	127.0
at	255.0	253.6	213.5	183.4	179.5	169.6	152.5	145.0	132.5	126.6	125.5	122.9	106.9	98.7	94.6	89.6	90.4	91.5	91.9	84.9
pt	366.6	290.8	314.3	325.4	301.0	286.4	245.3	246.4	217.2	234.8	214.8	184.4	176.9	175.2	172.6	172.6	155.0	154.7	157.7	145.2
fi	426.8	308.2	247.0	212.6	175.5	189.0	215.2	197.7	160.5	143.3	139.8	150.1	166.7	196.9	185.8	153.7	174.6	155.3	133.9	136.8
se	216.9	183.1	164.5	150.6	125.8	126.5	122.1	113.9	103.2	88.2	75.5	73.2	76.2	85.8	85.5	74.9	77.7	67.4	68.0	66.4
uk	409.6	326.0	301.1	287.3	256.6	248.2	266.8	258.0	224.2	210.6	206.4	197.4	186.2	186.4	173.4	175.4	169.8	129.0	121.5	117.6
AVG	**382.2**	**322.1**	**283.7**	**260.9**	**241.3**	**233.9**	**220.9**	**213.7**	**194.4**	**184.5**	**174.2**	**170.4**	**161.7**	**160.0**	**152.7**	**142.5**	**142.5**	**130.2**	**125.0**	**120.3**
COV	**0.08**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.08**	**0.09**	**0.09**	**0.09**	**0.09**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.07**	**0.07**	**0.07**	**0.07**

Note: **AVG** **Weighted average (weights according to the ratio national vs. total GDP)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt 2000)
CO_2 emission data from CDIAC (2002)
GDP data from Eurostat (2001)

Anthropogenic SO_2 emissions / GDP (tonnes / million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	9.60	8.06	7.91	6.13	5.07	3.75	3.27	2.98	2.71	2.29	2.42	2.05	1.83	1.61	1.28	1.16	1.12	1.01	0.93	0.79
dk	9.71	7.43	6.92	5.31	4.60	4.68	3.63	3.03	2.89	2.16	1.87	2.39	1.77	1.38	1.31	1.14	1.31	0.78	0.52	0.36
de	5.41	4.91	4.24	3.61	3.27	2.87	2.45	1.97	1.20	0.87	4.46	2.84	2.16	1.80	1.43	1.09	0.77	0.61	0.48	0.43
gr	11.07	10.22	9.11	9.62	9.27	9.63	10.54	10.54	9.21	8.31	7.69	7.53	7.22	6.96	6.26	6.15	5.52	4.99	4.98	4.57
es	18.64	16.79	15.07	15.75	12.59	10.99	9.43	8.24	6.00	6.02	5.19	4.71	4.50	4.61	4.55	3.94	3.21	3.20	2.89	2.59
fr	6.68	4.80	4.28	3.36	2.80	2.15	1.81	1.73	1.50	1.58	1.36	1.44	1.20	1.00	0.89	0.80	0.76	0.63	0.63	0.51
ie	16.67	12.22	8.75	7.47	6.98	6.33	6.79	7.12	5.79	5.60	5.84	5.33	4.74	4.38	4.35	3.69	3.01	2.91	2.87	2.30
it	11.57	9.16	7.00	5.30	4.07	3.42	3.16	3.11	2.79	2.37	1.94	1.68	1.51	1.61	1.51	1.61	1.28	1.07	1.00	0.85
lu	6.05	4.86	3.47	2.58	2.52	2.38	2.16	2.04	1.87	1.63	1.43	1.30	1.23	1.14	0.91	0.59	0.51	0.38	0.23	0.21
nl	3.97	3.61	2.84	2.12	1.87	1.52	1.45	1.40	1.29	0.98	0.91	0.74	0.70	0.62	0.52	0.48	0.43	0.37	0.31	0.28
at	6.86	5.52	4.58	3.09	2.58	2.18	1.80	1.50	1.08	0.89	0.73	0.61	0.44	0.39	0.35	0.32	0.30	0.28	0.25	0.21
pt	13.20	11.66	11.52	12.20	9.70	6.79	7.09	6.17	5.02	5.90	6.68	5.51	5.62	5.05	4.59	4.58	3.83	3.86	3.97	3.42
fi	16.06	12.06	9.56	6.92	5.84	5.52	4.74	4.39	3.50	2.42	2.52	2.05	1.79	1.79	1.44	1.03	1.10	0.96	0.83	0.76
se	5.47	4.23	3.69	2.99	2.48	2.05	2.05	1.66	1.48	0.94	0.68	0.51	0.48	0.57	0.51	0.47	0.44	0.26	0.25	0.31
uk	12.62	9.60	8.47	7.45	6.72	6.19	6.83	6.53	5.60	5.02	4.99	4.43	4.28	3.88	3.12	2.79	2.21	1.44	1.29	0.95
AVG	**10.24**	**8.34**	**7.16**	**6.26**	**5.36**	**4.70**	**4.48**	**4.16**	**3.46**	**3.13**	**3.25**	**2.87**	**2.63**	**2.45**	**2.20**	**1.99**	**1.72**	**1.52**	**1.43**	**1.24**
COV	**0.11**	**0.11**	**0.12**	**0.15**	**0.15**	**0.15**	**0.16**	**0.17**	**0.17**	**0.19**	**0.18**	**0.18**	**0.20**	**0.20**	**0.21**	**0.23**	**0.22**	**0.24**	**0.26**	**0.27**

Note: **AVG** **Weighted average (weights according to the ratio national vs. total GDP)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt 2000)
CO_2 emission data from CDIAC (2002)
GDP data from Eurostat (2001)

Anthropogenic NO2 emissions / GDP (tonnes / million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	5.124	4.744	4.511	4.082	3.552	3.051	2.748	2.745	2.642	2.516	2.206	2.059	1.978	1.849	1.729	1.584	1.473	1.407	1.373	1.238
dk	5.867	4.877	4.823	4.230	4.067	3.976	3.996	3.573	3.350	3.025	2.782	3.114	2.522	2.395	2.260	1.929	2.135	1.769	1.566	1.352
de	4.471	4.151	3.772	3.485	3.298	3.083	2.799	2.510	2.269	1.975	2.268	1.774	1.502	1.338	1.181	1.076	1.025	0.972	0.903	0.839
gr	7.984	7.119	6.145	6.296	5.893	5.891	6.587	6.716	5.988	5.497	4.956	4.565	4.339	4.179	4.071	3.809	3.863	3.390	3.525	3.212
es	6.698	5.732	5.182	5.464	4.771	4.289	3.979	3.863	3.461	3.206	2.928	2.779	2.737	2.886	2.946	2.786	2.561	2.665	2.576	2.470
fr	4.190	3.633	3.313	3.129	2.916	2.641	2.390	2.352	2.226	2.124	1.991	2.001	1.865	1.682	1.563	1.463	1.404	1.335	1.247	1.154
ie	5.481	5.475	4.762	4.470	4.129	4.113	4.191	4.703	4.650	4.394	3.706	3.556	3.585	3.234	2.857	2.639	2.460	2.069	1.986	1.742
it	5.043	4.414	3.945	3.405	3.070	2.904	2.771	2.773	2.633	2.451	2.282	2.164	2.172	2.404	2.126	2.157	1.847	1.662	1.539	1.375
lu	5.802	5.212	4.493	3.865	3.529	3.128	2.939	2.881	2.726	2.465	2.196	2.063	2.020	1.897	1.606	1.386	1.414	1.135	0.997	0.894
nl	4.728	4.478	3.950	3.639	3.578	3.476	3.224	3.180	3.101	2.818	2.610	2.426	2.252	2.011	1.802	1.639	1.598	1.402	1.245	1.145
at	4.062	3.636	3.161	2.800	2.616	2.489	2.230	2.057	1.891	1.698	1.540	1.465	1.296	1.125	1.103	0.968	0.924	0.949	0.901	0.861
pt	8.235	7.243	7.192	7.652	5.236	3.291	3.331	3.281	3.002	2.783	5.893	5.301	4.874	4.792	4.670	4.481	4.201	4.082	3.906	3.682
fi	8.110	6.232	5.355	4.859	4.081	3.973	3.970	3.851	3.400	2.987	2.904	3.058	3.609	4.112	3.567	2.774	2.810	2.532	2.318	2.148
se	4.500	4.095	4.096	3.928	3.441	3.284	3.255	3.172	2.862	2.465	1.927	1.803	1.785	2.130	2.060	1.773	1.592	1.398	1.316	1.291
uk	6.671	5.416	4.995	4.806	4.445	4.188	4.575	4.562	4.057	3.756	3.661	3.267	3.169	2.946	2.646	2.479	2.213	1.617	1.421	1.289
AVG	**5.798**	**5.097**	**4.646**	**4.407**	**3.908**	**3.585**	**3.532**	**3.481**	**3.217**	**2.944**	**2.923**	**2.760**	**2.647**	**2.599**	**2.413**	**2.196**	**2.101**	**1.892**	**1.788**	**1.646**
COV	**0.06**	**0.06**	**0.06**	**0.07**	**0.06**	**0.06**	**0.08**	**0.08**	**0.08**	**0.08**	**0.10**	**0.10**	**0.10**	**0.10**	**0.11**	**0.11**	**0.11**	**0.12**	**0.13**	**0.13**

Note: AVG Weighted average (weights according to the ratio national vs. total GDP)
COV Coefficient of variation

Emission data (except CO_2) from EMEP (2002, es/gr/pt 2000)
CO_2 emission data from CDIAC (2002)
GDP data from Eurostat (2001)

Anthropogenic NMVOC emissions / GDP (tonnes / million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be						6.458	5.175	4.337	3.607	2.868	2.303	1.924	1.805	1.686	1.542	1.386	1.277	1.241	1.219	1.149
dk	4.359	3.990	3.634	3.324	3.100	2.678	2.465	2.338	2.219	2.124	1.733	1.656	1.520	1.423	1.260	1.127	1.072	0.967	0.904	0.823
de	4.309	4.000	3.675	3.331	3.140	2.970	2.700	2.510	2.334	2.112	2.699	1.989	1.656	1.421	1.251	1.107	1.035	0.985	0.911	0.847
gr						11.820	11.911	10.872	8.606	6.946	5.078	4.634	4.417	4.393	4.250	4.043	3.843	3.606	3.663	3.363
es	16.907	15.418	13.747	14.501	12.732	11.913	10.902	10.318	9.110	7.822	7.067	6.286	5.847	5.966	6.545	6.036	5.395	5.621	5.356	5.062
fr											2.626	2.527	2.362	2.151	1.927	1.768	1.660	1.564	1.456	1.345
ie											3.455	3.289	3.144	2.935	2.659	2.386	2.255	1.999	1.872	1.391
it	6.708	5.831	5.097	4.399	3.861	3.585	3.310	3.198	3.017	2.832	2.605	2.502	2.527	2.832	2.792	2.889	2.049	1.860	1.703	1.547
lu						2.234	2.160	2.174	2.108	1.951	1.814	1.603	1.519	1.366	1.257	1.056	1.028	0.945	0.762	0.829
nl						2.962	2.685	2.575	2.771	2.258	2.259	1.974	1.774	1.522	1.375	1.201	1.155	0.981	0.877	0.791
at	6.297	5.812	5.076	4.603	4.407	4.132	3.914	3.700	3.543	3.213	2.756	2.346	1.947	1.732	1.574	1.478	1.392	1.352	1.246	1.163
pt						6.822	7.117	7.664	7.554	7.232	7.063	6.511	6.000	6.225	5.994	5.780	5.184	5.642	5.117	4.946
fi								2.808	2.472	2.144	2.023	2.173	2.580	2.844	2.378	1.989	1.814	1.685	1.582	1.461
se									3.676	3.185	2.999	2.750	2.631	3.175	2.975	2.693	2.415	2.159	2.115	2.083
uk	6.136	5.099	4.794	4.631	4.455	4.082	4.419	4.337	3.880	3.631	3.529	3.219	3.093	2.982	2.740	2.629	2.366	1.798	1.573	1.402
AVG											**3.334**	**3.026**	**2.855**	**2.844**	**2.701**	**2.505**	**2.263**	**2.160**	**2.024**	**1.880**
COV											**0.13**	**0.13**	**0.13**	**0.14**	**0.16**	**0.16**	**0.16**	**0.18**	**0.18**	**0.19**

Note: **AVG** **Weighted average (weights according to the ratio national vs. total GDP)**
COV **Coefficient of variation**

Emission data (except CO_2) from EMEP (2002, es/gr/pt 2000)
CO_2 emission data from CDIAC (2002)
GDP data from Eurostat (2001)

Anthropogenic CO emissions / GDP (tonnes / million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be											7.24	6.89	6.56	5.99	5.33	4.87	4.70	4.36	4.25	4.00
dk	20.54	21.56	20.51	15.64	15.95	13.52	12.40	11.95	10.65	10.93	7.21	7.11	6.46	5.94	5.19	4.64	4.57	4.01	4.06	3.48
de	18.80	16.38	14.17	12.36	11.72	10.89	9.81	8.91	8.15	7.25	9.40	6.77	5.45	4.71	4.10	3.65	3.40	3.18	2.82	2.54
gr											20.19	18.77	17.12	16.63	15.58	14.97	14.16	13.19	13.84	12.15
es	24.12	21.44	19.24	20.16	17.53	15.96	14.66	13.99	12.85	11.34	9.87	9.17	9.00	9.33	9.36	7.90	7.86	8.17	7.81	7.41
fr	32.74	28.47	25.72	23.85	22.39	20.26	18.20	17.27	15.81	14.05	11.50	11.03	10.11	9.17	8.11	7.63	6.90	6.42	5.96	5.41
ie											12.59	11.68	10.89	9.51	8.17	6.98	6.29	5.47	5.18	4.17
it	23.36	20.58	18.50	15.99	14.60	13.84	12.47	11.75	10.77	9.89	9.21	8.73	8.60	9.37	8.97	9.46	7.38	6.68	6.10	5.60
lu											16.71	19.71	16.75	16.62	10.12	7.06	6.62	5.04	2.99	2.77
nl						8.15	6.88	6.33	6.07	5.46	5.14	4.38	3.98	3.61	3.21	2.94	2.88	2.32	2.12	1.91
at	30.51	27.14	22.92	20.12	19.53	17.78	17.23	15.76	14.54	12.98	10.45	9.61	8.37	7.58	6.99	5.96	5.72	5.64	5.12	4.36
pt											20.71	18.94	17.66	17.79	16.71	15.04	13.96	12.93	11.58	11.31
fi											5.41	5.82	6.07	6.66	5.62	4.69	4.83	4.62	4.16	4.76
se											6.90	6.45	6.38	7.55	7.11	6.41	5.70	4.98	5.14	4.57
uk	19.77	16.51	15.31	14.25	13.42	11.86	12.56	12.09	10.63	10.13	9.50	8.64	8.24	7.67	6.85	6.52	6.01	4.55	4.07	3.83
AVG											**10.80**	**10.25**	**9.44**	**9.21**	**8.09**	**7.25**	**6.73**	**6.10**	**5.68**	**5.22**
COV											**0.11**	**0.12**	**0.12**	**0.12**	**0.12**	**0.12**	**0.12**	**0.13**	**0.14**	**0.14**

Note: AVG Weighted average (weights according to the ratio national vs. total GDP)
COV Coefficient of variation

Emission data (except CO_2) from EMEP (2002, es/gr/pt 2000)
CO_2 emission data from CDIAC (2002)
GDP data from Eurostat (2001)

Anthropogenic NH_3 emissions / GDP (tonnes / million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be						0.835	0.806	0.780	0.766	0.726	0.696	0.572	0.530	0.526	0.485	0.457	0.461	0.455	0.449	0.437
dk	2.684	2.466	2.191	1.958	1.730	1.837	1.677	1.541	1.451	1.403	1.309	1.224	1.134	1.049	0.937	0.807	0.736	0.707	0.681	0.617
de	0.977	0.909	0.843	0.780	0.743	0.714	0.638	0.592	0.551	0.512	0.641	0.479	0.423	0.390	0.370	0.347	0.347	0.341	0.334	0.320
gr											1.201	1.069	0.974	0.947	0.869	0.949	0.746	0.667	0.683	0.615
es	2.603	2.318	2.243	2.342	2.081	1.929	1.809	1.826	1.596	1.381	1.196	1.075	1.033	1.075	1.141	1.070	1.109	1.060	1.021	0.975
fr											0.844	0.816	0.767	0.729	0.699	0.672	0.663	0.656	0.632	0.607
ie											3.518	3.408	3.227	3.180	2.957	2.753	2.501	2.157	2.068	1.859
it	1.475	1.307	1.140	1.084	0.925	0.876	0.812	0.761	0.709	0.615	0.549	0.492	0.476	0.543	0.546	0.562	0.456	0.443	0.423	0.415
lu											0.668	0.607	0.575	0.531	0.489	0.462	0.450	0.441	0.411	0.405
nl	1.898	1.869	1.715	1.600	1.536	1.464	1.417	1.370	1.221	1.120	1.017	0.974	0.729	0.718	0.587	0.480	0.466	0.582	0.500	0.491
at	1.398	1.309	1.150	1.055	1.000	0.935	0.849	0.789	0.740	0.698	0.639	0.591	0.530	0.491	0.461	0.421	0.405	0.397	0.379	0.354
pt											1.945	1.595	1.466	1.392	1.255	1.274	1.175	1.137	1.090	0.978
fi											0.368	0.417	0.521	0.570	0.471	0.378	0.367	0.370	0.348	0.306
se									0.358	0.310	0.291	0.271	0.331	0.401	0.380	0.359	0.322	0.306	0.302	0.272
uk											0.485	0.447	0.427	0.429	0.404	0.400	0.368	0.299	0.287	0.280
AVG											**1.024**	**0.936**	**0.876**	**0.865**	**0.803**	**0.760**	**0.705**	**0.668**	**0.640**	**0.595**
COV											**0.20**	**0.21**	**0.21**	**0.20**	**0.20**	**0.20**	**0.20**	**0.18**	**0.18**	**0.17**

Note: AVG Weighted average (weights according to the ratio national vs. total GDP)
COV Coefficient of variation

Emission data (except CO_2) from EMEP (2002, es/gr/pt 2000)
CO_2 emission data from CDIAC (2002)
GDP data from Eurostat (2001)

Table 28 Manufacturing emissions / manufacturing GDP

SO_2 Emissions by Combustion, Manufacturing Sector (tonnes) / Manufactoring GDP (million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
be						10.73					8.46	7.76	8.45	7.86	4.03	4.14		
dk						10.57	6.46	5.18	4.29	2.89	2.85	2.88	2.41	2.05	2.02	1.49		
de								10.12	8.70	7.47	5.56	3.79	2.81	2.12	1.50	1.22		
gr						31.33	25.33	23.33	21.60	18.41	18.54	16.84	14.33	13.90	12.95	12.84		
es	53.63	51.75	39.31	33.22	25.66	22.10	20.06	18.68	18.96	15.14	14.72	13.84	12.58	13.24	12.12	10.12		
fr											3.23	3.28	2.75	2.36	2.27	1.89		
ie											10.57	8.34	7.31	7.50	7.71	5.52		
it	45.72	34.63	25.07	20.11	13.14	8.90	7.62	6.24	5.84	5.13	4.41	4.03	3.73	2.96	2.29	2.08		
lu						23.45					15.68	16.48	15.74	15.30	11.73	6.58		
nl						7.74					2.86	2.34	2.09	1.95	1.77	1.62		
at	35.88	29.31	23.64	13.16	7.88	6.27	4.98	4.00	2.80	1.84	1.78	1.16	0.77	0.63	0.50	0.58		
pt											17.14	13.38	13.52	12.01	11.15	11.39		
fi											12.06	6.12	3.40	2.23	2.17	1.42		
se											1.25	0.99	0.75	0.82	0.64	0.52		
uk	31.65	24.36	20.31	16.28	12.76	10.57	11.50	9.42	9.34	7.53	5.84	5.49	5.49	5.33	4.32	3.08		
AVG											**8.33**	**7.11**	**6.41**	**6.02**	**5.14**	**4.30**		
COV											**0.18**	**0.19**	**0.20**	**0.22**	**0.22**	**0.24**		

Note: AVG **Weighted average (weights according to the ratio national vs. total manufactoring GDP)**
COV **Coefficient of variation**

Emission data from EMEP (2002, es/gr/pt: 2000)
GDP data from Eurostat (2001)

Data on the GDP share of the manufactoring sector:
All countries except Ireland and Luxembourg: OECD (2000)
Ireland-- data extrapolated from Central Statistics Office, Ireland (2001)
Luxembourg-- Eurostat (2001)

Emissions by combustion in manufacuring industry (Snap 3) of NO_2 (tonnes) / manufactoring GDP (million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
be						3.45					4.18	3.77	4.17	4.13	3.82	3.43		
dk						2.34	2.06	1.83	1.56	1.40	1.41	1.40	1.28	1.15	1.06	0.83		
de								3.17	2.86	2.47	1.98	1.80	1.55	1.44	1.33	1.27		
gr						3.45	3.05	3.06	3.10	2.86	3.11	3.05	2.80	2.94	2.95	3.14		
es	14.63	14.35	12.67	10.52	8.28	7.03	6.41	6.21	6.18	5.21	5.06	5.09	4.56	4.61	4.34	3.76		
fr											1.56	1.49	1.34	1.24	1.23	1.05		
ie											2.94	2.47	2.08	2.08	1.91	1.60		
it	9.98	9.11	8.10	7.28	6.34	5.58	5.10	4.75	4.39	3.93	3.40	3.66	3.31	2.56	1.88	1.77		
lu						17.02					13.44	14.03	13.32	12.96	10.73	8.80		
nl						6.48					3.48	3.32	2.96	2.59	2.43	2.12		
at	7.99	6.61	5.47	3.86	3.02	2.85	2.35	2.04	1.73	1.39	1.34	1.06	0.95	0.80	0.72	0.72		
pt											4.66	4.28	4.36	4.36	4.24	3.83		
fi											2.84	2.58	3.37	2.84	2.53	1.95		
se											1.30	1.26	1.04	1.03	0.83	0.70		
uk	9.29	7.97	7.52	7.34	6.39	5.18	5.03	4.59	4.21	3.56	2.73	2.39	2.19	2.10	2.06	1.73		
AVG											**3.56**	**3.44**	**3.29**	**3.12**	**2.80**	**2.45**		
COV											**0.21**	**0.23**	**0.23**	**0.24**	**0.22**	**0.21**		

Note: **AVG** **Weighted average (weights according to the ratio national vs. total manufactoring GDP)**
COV **Coefficient of variation**

Emission data from EMEP (2001)
GDP data from Eurostat (2000)

Data on the GDP share of the manufactoring sector:
All countries except Ireland and Luxembourg: OECD (2000)
Ireland-- data extrapolated from Central Statistics Office, Ireland (2001)
Luxembourg-- Eurostat (2000)

Emissions by combustion in manufacuring industry (Snap 3) of NMVOC (tonnes) / manufactoring GDP (million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
be						1.18					0.26	0.17	0.23	0.17	0.16	0.14		
dk						0.18	0.17	0.19	0.15	0.11	0.12	0.11	0.10	0.09	0.07	0.05		
de								0.11	0.10	0.08	0.07	0.06	0.05	0.05	0.05	0.04		
gr						1.72	1.45	1.39	1.34	1.19	1.25	1.18	1.05	1.06	1.03	1.07		
es	0.92	0.86	0.78	0.63	0.51	0.47	0.42	0.40	0.39	0.32	0.32	0.33	0.32	0.33	0.28	0.22		
fr											0.10	0.09	0.08	0.08	0.08	0.07		
ie											0.08	0.08	0.04	0.04	0.04	0.02		
it	0.38	0.35	0.31	0.28	0.24	0.21	0.19	0.18	0.17	0.15	0.13	0.12	0.10	0.07	0.09	0.07		
lu						0.76					0.50	0.90	1.21	1.52	0.33	0.20		
nl						0.40					0.19	0.19	0.20	0.14	0.11	0.20		
at	0.30	0.26	0.23	0.17	0.15	0.15	0.12	0.11	0.10	0.09	0.08	0.07	0.07	0.06	0.02	0.03		
pt											1.71	1.54	1.48	1.46	1.44	1.18		
fi																		
se											0.34	0.33	0.35	0.33	0.26	0.21		
uk	0.24	0.22	0.20	0.20	0.18	0.15	0.14	0.13	0.12	0.10	0.08	0.07	0.06	0.06	0.06	0.05		
AVG											**0.37**	**0.37**	**0.38**	**0.39**	**0.29**	**0.25**		
COV											**0.32**	**0.31**	**0.31**	**0.34**	**0.36**	**0.36**		

Note: AVG Weighted average (weights according to the ratio national vs. total manufactoring GDP)
COV Coefficient of variation

Emission data from EMEP (2002, es/gr/pt: 2000)
GDP data from Eurostat (2001)

Data on the GDP share of the manufactoring sector:
All countries except Ireland and Luxembourg: OECD (2000)
Ireland– data extrapolated from Central Statistics Office, Ireland (2001)
Luxembourg– Eurostat (2001)

Table 29 Pollution load index

Belgium

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											2	6	8	13	15	16	22	24	27	25
CO_2	51	48	47	29	34	30	28	27	17	21	32	25	27	24	29	31	28	27	22	24
SO_2	31	25	30	16	12	-5	-9	-8	0	-7	-17	-17	-14	-12	-17	-11	0	4	5	4
NO_2	21	19	13	7	0	-7	-11	-6	-4	-1	-6	-6	-2	2	7	9	4	5	10	7
NMVOC						59	37	21	5	-9	-21	-27	-25	-22	-22	-23	-23	-23	-19	-17
CO											-19	-15	-10	-8	-7	-6	-4	-6	-1	2
NH_3						-16	-13	-11	-4	0	4	-7	-5	1	0	2	4	2	5	6
PLI 7											-4	-6	-3	0	1	2	4	5	7	7

Denmark

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	0	0	0	0	0	0	0	0	0	0	3	-1	-9	-14	-15	-15	-13	-14	-17	-21
CO_2	33	24	18	9	6	23	43	41	32	33	38	23	16	22	32	28	43	41	27	34
SO_2	91	93	86	57	67	85	63	67	72	41	17	-4	-24	-27	-25	-31	-13	-8	-12	-4
NO_2	67	61	59	53	50	61	59	62	65	69	68	64	64	70	77	67	76	78	78	81
NMVOC	0	0	0	0	0	0	0	-5	-5	-3	-6	-4	-2	-2	-4	-3	-4	-2	0	2
CO	0	0	0	0	0	0	0	0	0	0	-18	-16	-24	-24	-22	-21	-13	-7	-8	16
NH_3	0	0	0	0	0	0	0	0	0	0	-27	-21	-16	-19	-23	-27	-28	-23	-23	-29
PLI 7											11	6	1	1	3	0	7	10	6	11

Germany

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	57	54	49	43	54	45	41	37	34	32	29	15	7	0	-5	-8	-13	-12	-14	-16
CO_2	51	49	47	52	59	52	55	51	53	42	13	44	42	42	47	36	35	35	32	37
SO_2	-24	-19	-19	-14	-9	-11	-15	-26	-50	-62	74	33	16	12	2	-13	-33	-40	-51	-48
NO_2	18	18	19	23	26	23	21	11	4	-6	-7	-16	-21	-22	-25	-25	-28	-29	-30	-30
NMVOC	-13	-14	-13	-13	-12	-13	-12	-14	-19	-22	-11	-22	-28	-32	-37	-39	-40	-42	-43	-43
CO	6	0	-4	-5	-4	-3	-2	-4	-7	-12	5	-12	-21	-24	-27	-29	-31	-33	-37	-39
NH_3	-15	-16	-15	-16	-13	-12	-16	-19	-18	-18	-9	-19	-20	-21	-21	-21	-22	-24	-23	-24
PLI 7											13	3	-4	-7	-9	-14	-19	-21	-24	-23

Greece

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											-26	-24	-22	-20	-17	-15	-11	-7	-4	-4
CO_2	-41	-39	-35	-29	-27	-25	-26	-21	-15	-10	-8	-24	-13	-12	-8	-8	-6	-3	-1	-2
SO_2	-37	-27	-18	-5	6	19	21	26	41	44	12	35	49	62	72	99	126	153	172	211
NO_2	-20	-17	-16	-15	-13	-13	-13	-12	-11	-9	-12	-9	-7	-4	4	7	21	21	32	37
NMVOC						40	28	16	3	-7	-27	-23	-20	-15	-12	-8	3	7	14	19
CO											-4	2	2	8	13	19	29	37	52	52
NH_3											-26	-24	-25	-25	-27	-14	-27	-30	-27	-28
PLI 7											-13	-10	-5	-1	3	11	19	25	34	41

Spain

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	-54	-52	-47	-47	-43	-45	-41	-37	-35	-31	-30	-27	-23	-19	-14	-11	-1	5	10	13
CO_2	-43	-40	-38	-38	-42	-41	-46	-44	-42	-36	-32	-37	-32	-37	-33	-28	-31	-25	-25	-27
SO_2	19	30	38	57	54	55	49	45	33	67	20	36	50	56	72	73	74	107	107	126
NO_2	-30	-33	-33	-32	-32	-34	-33	-31	-29	-22	-20	-14	-9	-8	-2	2	1	14	20	28
NMVOC	68	69	66	67	66	65	67	70	68	74	74	78	79	75	96	98	103	124	134	146
CO	-46	-46	-45	-43	-45	-43	-41	-39	-34	-30	-29	-24	-18	-17	-13	-20	-11	0	5	11
NH_3	3	0	6	3	5	4	7	17	22	27	19	24	28	24	31	31	46	40	42	44
PLI 7											0	5	11	11	19	21	26	38	42	49

France

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											-12	-8	-5	0	3	5	9	3	3	-1
CO_2	0	-6	-6	-9	-13	-17	-20	-25	-26	-25	-21	-23	-26	-26	-33	-29	-27	-31	-26	-22
SO_2	-10	-23	-22	-30	-33	-41	-46	-45	-44	-34	-54	-43	-47	-49	-47	-45	-38	-41	-34	-38
NO_2	0	-2	-4	-6	-6	-8	-12	-13	-13	-11	-11	-6	-6	-8	-6	-5	-5	-3	-3	-3
NMVOC											-3	0	1	0	-5	-6	-3	-6	-6	-7
CO	106	102	99	97	95	98	93	89	85	76	50	54	55	54	49	53	47	45	46	42
NH_3											43	49	52	51	53	55	57	57	56	56
PLI 7											-1	3	3	3	2	4	6	3	5	4

Ireland

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											202	212	221	234	243	249	269	284	283	280
CO_2	-18	-13	-11	-10	-9	-10	3	8	10	1	10	12	8	11	16	15	16	23	27	21
SO_2	1	-4	-17	-18	-12	-7	10	23	20	32	19	27	33	36	65	66	72	119	143	143
NO_2	-43	-31	-31	-32	-33	-27	-21	-11	-5	0	-7	-5	6	1	2	5	10	12	18	19
NMVOC											-30	-27	-22	-23	-23	-23	-14	-10	-7	-21
CO											-16	-15	-11	-17	-18	-22	-18	-14	-10	-17
NH_3											214	235	251	254	260	265	265	261	268	265
PLI 7											56	63	69	71	78	79	86	97	103	99

Italy

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	-40	-39	-40	-38	-35	-39	-38	-37	-35	-35	-34	-30	-29	-22	-17	-16	-36	-32	-31	-31
CO_2	-30	-27	-26	-27	-25	-25	-26	-22	-20	-18	-12	-21	-17	-18	-20	-15	-20	-16	-15	-19
SO_2	3	1	-9	-14	-21	-25	-22	-14	-6	-10	-40	-38	-38	-35	-31	-19	-15	-14	-12	-12
NO_2	-26	-24	-24	-25	-24	-23	-20	-15	-13	-10	-8	-4	0	4	-3	-1	-1	-1	-3	-6
NMVOC	-19	-20	-22	-24	-26	-26	-25	-23	-22	-18	-16	-9	-2	3	5	10	-6	-9	-11	-13
CO	-25	-23	-20	-19	-18	-12	-12	-10	-10	-6	-1	7	12	16	19	29	19	19	16	16
NH_3	-24	-23	-27	-22	-26	-25	-25	-26	-22	-25	-25	-25	-24	-21	-19	-19	-25	-24	-25	-23
PLI 7											-20	-17	-14	-10	-9	-4	-12	-11	-12	-12

Luxembourg

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											8	5	7	19	6	10	19	22	17	20
CO_2	224	193	187	176	199	197	197	185	197	206	236	224	234	239	215	152	143	132	121	105
SO_2	1	-1	-15	-22	-10	3	3	5	15	14	-12	-4	4	13	8	-19	-19	-32	-53	-49
NO_2	69	71	69	62	63	63	63	63	66	68	66	72	81	90	80	68	77	49	44	40
NMVOC						-8	-4	0	2	7	12	12	14	15	15	4	10	4	-8	8
CO											236	349	317	367	222	142	140	92	26	27
NH_3											77	82	85	85	83	82	79	75	72	78
PLI 7											89	106	106	119	90	63	64	49	31	33

The Netherlands

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	19	7	7	23	34	44	25	25	23	24	52	57	54	55	55	52	69	55	50	45
CO_2	22	21	-3	3	13	18	14	16	13	25	31	19	20	28	17	24	32	30	29	27
SO_2	-48	-45	-49	-55	-56	-59	-58	-56	-54	-62	-71	-72	-70	-69	-69	-66	-64	-65	-66	-65
NO_2	11	13	11	9	13	16	13	13	13	9	7	6	6	6	5	6	8	1	-3	-3
NMVOC						-23	-26	-27	-21	-31	-25	-29	-31	-33	-35	-38	-34	-42	-44	-45
CO						-38	-43	-46	-45	-47	-45	-49	-49	-48	-48	-48	-45	-53	-53	-54
NH_3	69	76	76	70	72	70	75	71	60	57	49	56	24	33	15	0	0	28	14	17
PLI 7											0	-2	-6	-4	-9	-10	-5	-6	-10	-11

Austria

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	21	23	23	23	31	24	22	22	24	24	20	20	19	21	21	20	24	25	24	23
CO_2	-23	-12	-12	-14	-9	-11	-11	-10	-13	-14	-4	-9	-14	-13	-12	-11	-12	-7	-3	-9
SO_2	-22	-25	-24	-37	-39	-42	-46	-50	-58	-63	-74	-74	-79	-78	-77	-75	-73	-70	-71	-71
NO_2	-19	-19	-20	-20	-20	-19	-22	-25	-27	-30	-32	-30	-32	-34	-29	-31	-32	-26	-24	-21
NMVOC	3	5	5	6	7	7	11	11	9	7	0	-6	-14	-14	-17	-14	-12	-12	-12	-11
CO	34	34	32	34	37	37	48	46	44	39	24	26	23	25	29	21	24	29	27	18
NH_3	1	3	2	2	3	2	0	-3	-1	1	0	2	0	0	0	-2	-5	-6	-7	-9
PLI 7											-9	-10	-14	-13	-12	-13	-12	-10	-10	-11

Portugal

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											11	16	18	20	25	26	33	38	40	40
CO_2	-70	-70	-64	-63	-64	-62	-63	-60	-59	-50	-45	-50	-43	-43	-42	-37	-43	-38	-33	-36
SO_2	-59	-53	-47	-38	-45	-54	-45	-46	-44	-20	-19	-13	14	10	15	36	39	68	95	106
NO_2	-56	-52	-49	-47	-62	-73	-70	-69	-67	-64	-12	-6	4	5	10	19	20	28	35	42
NMVOC						-56	-48	-40	-33	-24	-14	-3	8	15	16	25	27	48	48	60
CO											-18	-8	4	9	12	13	15	17	16	28
NH_3											2	2	13	6	-1	9	6	6	9	5
PLI 7											-14	-9	2	3	5	13	14	24	30	35

Finland

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											3	-1	-9	-14	-15	-15	-13	-14	-17	-21
CO_2	33	24	18	9	6	23	43	41	32	33	38	23	16	22	32	28	43	41	27	34
SO_2	91	93	86	57	67	85	63	67	72	41	17	-4	-24	-27	-25	-31	-13	-8	-12	-4
NO_2	67	61	59	53	50	61	59	62	65	69	68	64	64	70	77	67	76	78	78	81
NMVOC								-5	-5	-3	-6	-4	-2	-2	-4	-3	-4	-2	0	2
CO											-18	-16	-24	-24	-22	-21	-13	-7	-8	16
NH_3											-27	-21	-16	-19	-23	-27	-28	-23	-23	-29
PLI 7											11	6	1	1	3	0	7	10	6	11

Sweden

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											-35	-34	-33	-31	-34	-35	-31	-38	-38	-27
CO_2	-4	-3	-10	-15	-16	-10	-10	-13	-14	-20	-27	-31	-28	-32	-29	-35	-27	-34	-33	-34
SO_2	-9	-11	-19	-26	-22	-26	-22	-33	-26	-47	-69	-73	-73	-70	-69	-68	-61	-73	-72	-60
NO_2	31	41	40	37	41	46	46	45	43	37	9	11	10	13	20	12	14	7	5	11
NMVOC									47	43	39	42	37	43	42	40	50	39	42	50
CO											4	7	9	12	17	15	19	10	20	15
NH_3									-40	-41	-43	-41	-27	-27	-27	-27	-27	-30	-31	-35
PLI 7											-18	-17	-15	-13	-12	-14	-9	-17	-15	-11

United Kingdom

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	26	29	30	29	5	20	25	24	23	20	12	14	14	4	-2	-3	0	0	-4	2
CO_2	18	20	26	29	22	27	32	33	33	30	35	23	19	21	19	18	18	16	15	10
SO_2	43	45	48	52	58	75	90	99	126	121	59	71	83	81	69	61	58	42	43	18
NO_2	29	29	30	31	29	34	37	40	44	44	41	35	34	28	28	20	17	11	6	1
NMVOC	-10	-8	-6	-5	-3	-3	0	2	3	5	4	6	5	5	4	1	6	1	-3	-10
CO	-24	-21	-18	-18	-19	-18	-17	-16	-13	-9	-11	-10	-10	-12	-12	-15	-12	-13	-14	-14
NH_3											-43	-41	-43	-42	-42	-43	-44	-43	-42	-42
PLI 7											14	14	15	12	9	6	6	2	0	-5

Note: **PLI 7 based on all seven pollutants**

Emission data (except CO_2) from EMEP (2002, es/gr/pt: 2000)
CO_2 emission data from CDIAC (2001)
Population data from Eurostat (2000)

Table 30 General pollution intensity

Belgium

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											-7	-1	-1	-2	-3	-6	3	10	12	11
CO_2	23	30	41	28	33	28	23	21	13	18	20	18	16	7	8	7	8	12	8	9
SO_2	7	10	25	14	11	-7	-12	-12	-4	-10	-24	-22	-21	-24	-30	-28	-15	-8	-7	-8
NO_2	-1	4	9	5	0	-8	-14	-11	-7	-4	-14	-12	-10	-12	-10	-11	-12	-7	-3	-5
NMVOC						49	25	10	-1	-14	-28	-32	-31	-33	-35	-37	-35	-32	-28	-27
CO											-26	-20	-17	-20	-22	-23	-19	-17	-12	-10
NH_3						-18	-14	-13	-4	1	-5	-12	-13	-13	-16	-17	-12	-10	-8	-6
GPI 7											-12	-12	-11	-14	-15	-16	-12	-8	-5	-5
GPI 3	10	15	25	16	14	4	-1	-1	0	1	-6	-6	-5	-9	-11	-11	-6	-1	-1	-1

Denmark

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	-16	-11	-11	-15	-12	-22	-26	-28	-25	-20	-31	-25	-24	-23	-25	-28	-25	-23	-17	-23
CO_2	9	2	8	0	1	14	10	8	2	-11	-5	13	-1	1	5	-9	14	-3	-13	-4
SO_2	8	1	9	-1	0	17	-2	-11	3	-15	-41	-9	-24	-35	-28	-29	0	-30	-49	-58
NO_2	14	7	16	9	14	20	26	17	18	16	9	34	16	15	19	9	29	17	11	4
NMVOC	-34	-32	-32	-33	-33	-40	-42	-41	-40	-36	-45	-41	-42	-43	-47	-49	-45	-47	-47	-48
CO	-12	6	13	-5	4	-1	-3	0	-2	11	-26	-17	-18	-21	-24	-27	-21	-24	-16	-22
NH_3	89	89	83	73	67	88	86	79	88	101	81	91	90	77	66	49	42	42	42	34
GPI 7											-8	7	0	-4	-5	-12	-1	-10	-13	-17
GPI 3	10	3	11	3	5	17	11	5	7	-3	-13	13	-3	-6	-1	-10	14	-5	-17	-19

Germany

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	2	7	5	-3	6	2	-6	-9	-7	-5	19	-4	-15	-28	-32	-36	-35	-29	-30	-31
CO_2	6	12	9	8	14	12	9	4	10	6	4	20	12	3	6	-4	1	9	7	12
SO_2	-47	-39	-39	-39	-35	-34	-40	-49	-64	-71	61	11	-9	-19	-27	-39	-50	-52	-60	-57
NO_2	-17	-11	-12	-13	-10	-9	-15	-23	-25	-30	-14	-29	-38	-44	-46	-48	-46	-43	-43	-43
NMVOC	-46	-42	-41	-43	-41	-41	-44	-45	-44	-44	-18	-35	-43	-51	-55	-58	-55	-53	-53	-53
CO	-25	-25	-28	-31	-30	-26	-29	-32	-31	-32	-4	-26	-38	-45	-48	-50	-49	-46	-49	-50
NH_3	-48	-46	-45	-47	-43	-41	-44	-46	-41	-39	-16	-32	-37	-43	-43	-45	-41	-39	-38	-38
GPI 7											5	-14	-24	-32	-35	-40	-39	-36	-38	-37
GPI 3	-19	-13	-14	-15	-10	-10	-15	-22	-26	-32	17	1	-11	-20	-22	-30	-32	-29	-32	-29

Greece

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											64	65	68	69	72	73	74	75	86	76
CO_2	15	16	15	36	41	55	79	100	102	110	103	67	87	86	91	87	83	82	93	81
SO_2	23	39	44	81	105	145	192	218	237	237	148	194	222	242	258	304	341	378	428	474
NO_2	55	58	49	64	67	79	110	121	113	113	96	98	101	103	116	118	136	128	156	152
NMVOC						176	194	183	141	113	62	67	72	79	84	88	100	102	121	119
CO											112	122	121	127	135	143	152	158	195	181
NH_3											65	66	62	59	53	75	43	33	42	33
GPI 7											93	97	105	109	116	127	133	137	160	159
GPI 3	31	38	36	60	71	93	127	147	151	153	116	120	137	144	155	169	187	196	225	236

Spain

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	-14	-8	0	15	18	10	14	20	15	12	0	3	9	26	41	42	56	71	78	79
CO_2	6	14	17	31	17	17	3	3	0	2	-2	-11	-5	-2	9	15	8	22	21	16
SO_2	123	148	160	231	208	208	184	169	132	166	73	92	112	142	182	178	174	237	234	256
NO_2	32	28	27	44	37	32	27	28	23	25	16	21	28	42	60	63	60	86	94	103
NMVOC	210	219	212	261	241	215	205	206	189	173	150	151	152	170	222	218	219	265	278	288
CO	4	6	6	25	15	18	17	19	20	16	2	8	16	27	42	28	40	63	69	75
NH_3	99	91	105	129	123	115	120	137	130	119	72	75	81	91	114	110	131	129	129	128
GPI 7											44	49	56	71	96	93	98	125	129	135
GPI 3	54	64	68	102	87	85	71	67	52	64	29	34	45	61	84	85	81	115	117	125

France

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											-27	-18	-16	-15	-14	-13	-7	-9	-8	-12
CO_2	-23	-26	-25	-26	-27	-32	-35	-37	-37	-34	-35	-32	-35	-38	-43	-41	-38	-39	-34	-30
SO_2	-30	-40	-38	-42	-44	-52	-56	-54	-52	-43	-62	-50	-53	-57	-55	-54	-47	-48	-41	-44
NO_2	-23	-24	-24	-23	-21	-24	-29	-28	-26	-22	-26	-17	-17	-23	-21	-21	-19	-14	-14	-14
NMVOC											-20	-11	-11	-16	-21	-22	-17	-16	-16	-16
CO	60	59	61	66	67	69	62	64	64	59	24	37	37	29	25	27	25	29	30	27
NH_3											19	33	34	27	28	29	34	39	39	39
GPI 7											-18	-8	-9	-13	-14	-14	-10	-8	-6	-7
GPI 3	-25	-30	-29	-30	-31	-36	-40	-40	-38	-33	-41	-33	-35	-39	-40	-39	-35	-33	-30	-29

Ireland

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											372	401	401	414	405	393	396	368	357	327
CO_2	52	51	48	52	56	54	73	85	89	71	72	79	68	71	70	63	55	50	51	36
SO_2	86	66	38	39	52	58	84	111	107	122	86	105	107	110	143	135	131	168	190	173
NO_2	6	20	15	15	16	24	32	53	64	69	45	53	65	56	50	49	48	37	41	34
NMVOC											10	18	21	19	14	10	16	10	11	-11
CO											31	36	39	28	21	11	9	5	7	-6
NH_3											391	438	447	444	431	416	390	340	339	311
GPI 7											144	162	164	163	162	154	149	140	142	123
GPI 3	48	46	33	35	42	46	63	83	87	87	67	79	80	79	88	82	78	85	94	81

Italy

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	-23	-24	-26	-29	-28	-32	-34	-34	-31	-33	-37	-33	-29	-12	-3	5	-27	-24	-21	-22
CO_2	-9	-7	-9	-17	-17	-17	-21	-19	-16	-16	-17	-24	-17	-7	-6	8	-9	-5	-4	-8
SO_2	34	29	12	-2	-13	-17	-17	-10	-1	-8	-43	-40	-39	-26	-19	2	-3	-3	0	0
NO_2	-3	-3	-6	-14	-16	-15	-15	-11	-9	-7	-13	-8	-1	18	13	25	13	11	11	6
NMVOC	3	0	-5	-13	-19	-23	-25	-23	-21	-18	-20	-12	-3	17	23	39	6	3	1	-1
CO	0	2	2	-3	-6	1	-2	-2	-1	0	-6	2	11	31	40	62	35	34	32	31
NH_3	1	-4	-10	-9	-17	-17	-17	-19	-14	-19	-29	-28	-25	-11	-5	3	-15	-14	-14	-12
GPI 7											-23	-20	-15	1	6	21	0	0	1	-1
GPI 3	7	6	-1	-11	-15	-16	-18	-13	-9	-11	-24	-24	-19	-5	-4	11	0	1	2	-1

Luxembourg

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											-44	-46	-45	-43	-51	-49	-43	-39	-42	-41
CO_2	114	96	84	70	82	72	68	64	71	71	73	66	71	62	47	17	16	16	9	0
SO_2	-33	-34	-46	-52	-45	-41	-42	-40	-34	-36	-55	-51	-47	-46	-50	-63	-61	-66	-77	-75
NO_2	12	15	8	0	-1	-6	-8	-6	-4	-6	-14	-11	-8	-9	-16	-22	-15	-25	-29	-31
NMVOC						-50	-48	-45	-42	-41	-43	-43	-41	-45	-46	-52	-47	-48	-55	-47
CO											73	130	113	123	50	12	15	-4	-38	-38
NH_3											-9	-7	-5	-12	-15	-16	-14	-12	-15	-13
GPI 7											-3	6	5	4	-12	-25	-21	-25	-35	-35
GPI 3	31	26	16	6	12	9	6	6	11	10	1	1	6	2	-6	-23	-20	-25	-32	-35

The Netherlands

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	-6	-9	-10	4	18	29	11	14	19	23	45	54	51	41	39	32	49	41	36	30
CO_2	0	5	-17	-12	0	6	2	7	9	24	25	17	17	16	5	7	17	18	17	15
SO_2	-57	-52	-57	-62	-61	-63	-62	-60	-55	-62	-72	-73	-71	-72	-72	-71	-68	-68	-70	-68
NO_2	-9	-2	-5	-7	0	5	1	4	9	8	2	4	3	-4	-6	-8	-4	-8	-12	-13
NMVOC						-35	-37	-36	-25	-33	-29	-30	-33	-40	-42	-46	-42	-47	-49	-51
CO						-42	-47	-48	-45	-46	-48	-50	-50	-53	-54	-55	-51	-57	-57	-58
NH_3	34	45	45	43	51	52	60	62	61	62	41	53	21	21	3	-13	-12	16	3	6
GPI 7											-5	-3	-9	-13	-18	-22	-16	-15	-19	-20
GPI 3	-22	-16	-26	-27	-20	-17	-20	-17	-12	-10	-15	-17	-17	-20	-24	-24	-19	-19	-21	-22

Austria

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	14	18	14	10	19	13	8	7	12	14	5	7	4	-2	-2	-7	0	4	4	2
CO_2	-25	-13	-17	-22	-17	-18	-21	-20	-21	-20	-16	-19	-25	-29	-29	-31	-29	-22	-19	-24
SO_2	-24	-26	-29	-43	-44	-46	-52	-56	-62	-65	-77	-77	-81	-82	-81	-80	-78	-75	-76	-76
NO_2	-22	-20	-24	-28	-27	-26	-30	-34	-34	-36	-40	-38	-41	-47	-43	-46	-45	-38	-37	-35
NMVOC	-4	-1	-5	-7	-3	-7	-7	-6	-3	-3	-13	-16	-25	-31	-33	-33	-29	-26	-26	-26
CO	32	35	27	23	28	31	37	33	35	33	8	12	7	2	3	-5	-1	8	6	-2
NH_3	-5	-3	-7	-9	-6	-7	-9	-11	-7	-3	-13	-9	-13	-19	-20	-24	-23	-22	-22	-24
GPI 7											-21	-20	-25	-30	-29	-32	-29	-24	-24	-26
GPI 3	-24	-20	-23	-31	-30	-30	-34	-37	-39	-40	-45	-45	-49	-53	-51	-52	-51	-45	-44	-45

Portugal

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											195	183	159	168	182	172	185	197	194	184
CO_2	8	0	22	39	40	40	29	36	30	49	44	22	26	27	31	35	22	33	40	31
SO_2	47	59	82	129	113	70	93	83	80	136	114	113	148	145	159	195	199	262	311	318
NO_2	60	60	74	99	47	-1	5	7	5	6	133	131	127	133	149	157	157	175	184	189
NMVOC						55	72	96	109	122	127	137	135	156	162	171	172	220	212	226
CO											117	124	128	143	152	143	147	152	144	159
NH_3											170	150	146	136	122	136	128	129	129	113
GPI 7											129	123	124	130	137	144	144	167	173	174
GPI 3	38	40	59	89	67	36	42	42	38	64	97	89	100	102	113	129	126	157	178	179

Finland

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											-30	-20	-7	0	-10	-20	-16	-19	-23	-27
CO_2	26	6	-4	-10	-19	-8	13	9	-4	-10	-7	-1	18	43	41	20	38	34	19	23
SO_2	80	65	51	29	28	39	29	30	25	-5	-21	-22	-23	-15	-20	-35	-16	-13	-18	-12
NO_2	58	38	30	26	15	20	25	26	20	15	14	32	67	99	89	57	70	69	66	66
NMVOC								-29	-33	-36	-36	-23	-1	15	2	-9	-7	-7	-6	-7
CO											-44	-32	-23	-11	-17	-26	-16	-12	-14	7
NH_3											-50	-36	-14	-5	-18	-31	-30	-27	-28	-35
GPI 7											-25	-15	3	18	9	-6	3	4	-1	2
GPI 3	55	36	26	15	8	17	22	22	14	0	-5	3	21	43	36	14	31	30	22	26

Sweden

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4											-56	-54	-50	-37	-40	-42	-43	-46	-45	-34
CO_2	-37	-38	-37	-37	-42	-39	-37	-38	-39	-45	-50	-52	-47	-39	-36	-42	-40	-43	-40	-41
SO_2	-40	-44	-43	-45	-47	-50	-45	-52	-48	-64	-79	-81	-80	-73	-72	-71	-67	-77	-75	-64
NO_2	-14	-10	-1	1	-4	-1	2	3	0	-6	-25	-23	-19	2	8	0	-5	-8	-7	-1
NMVOC									1	-4	-5	-2	2	29	28	24	25	20	27	34
CO											-29	-25	-19	1	5	2	-1	-5	7	3
NH_3									-56	-58	-61	-59	-46	-34	-34	-35	-39	-40	-38	-42
GPI 7											-44	-42	-37	-21	-20	-23	-24	-28	-25	-21
GPI 3	-30	-31	-27	-27	-31	-30	-27	-29	-29	-38	-52	-52	-49	-37	-33	-38	-37	-42	-41	-35

United Kingdom

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	30	19	23	27	7	17	43	44	33	31	23	27	33	23	13	19	19	-3	-9	0
CO_2	25	15	21	28	24	26	50	53	43	42	48	38	39	43	38	45	41	13	9	6
SO_2	52	39	42	50	61	73	116	129	143	140	75	91	115	113	95	98	88	38	36	14
NO_2	36	24	25	30	31	33	56	62	54	56	54	50	56	51	47	48	40	8	1	-1
NMVOC	-9	-17	-13	-8	-3	-10	7	13	8	12	14	18	23	24	21	25	26	-1	-8	-12
CO	-18	-22	-19	-16	-15	-16	-2	2	-3	3	-2	1	5	3	1	4	5	-15	-18	-16
NH_3											-37	-35	-33	-32	-33	-30	-33	-45	-45	-44
GPI 7											25	27	34	32	26	30	27	-1	-5	-8
GPI 3	38	26	30	36	38	44	74	81	80	79	59	60	70	69	60	64	56	20	15	6

Note: **GPI 7 based on all seven pollutants**
GPI 3 based on CO_2, SO_2 and NO_2 emission figures

Emission data (except CO_2) from EMEP (2002, es/gr/pt: 2000)
CO_2 emission data from CDIAC (2001)
GDP data from Eurostat (2000)

Table 31 Manufacturing pollution intensity

Belgium

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											52	65	106	117	29	58				
NO_2											69	58	92	110	112	113				
NMVOC											90	24	84	51	43	44				
MPI 2											60	62	99	113	71	86				

Denmark

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											-50	-40	-43	-46	-36	-44				
NO_2											-45	-42	-43	-44	-43	-50				
NMVOC											-16	-17	-23	-23	-38	-51				
MPI 2											-47	-41	-43	-45	-40	-47				

Germany

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											-3	-27	-41	-52	-60	-61				
NO_2											-29	-33	-38	-36	-35	-30				
NMVOC											-62	-65	-67	-68	-63	-64				
MPI 2											-16	-30	-39	-44	-47	-45				

Greece

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											235	260	248	282	324	400				
NO_2											23	26	26	46	60	90				
NMVOC											838	845	780	899	914	1076				
MPI 2											129	143	137	164	192	245				

Spain

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											190	230	243	318	377	379				
NO_2											113	126	121	147	157	149				
NMVOC											141	169	172	222	185	138				
MPI 2											152	178	182	233	267	264				

France

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											-48	-36	-40	-42	-32	-33				
NO_2											-43	-44	-45	-43	-38	-42				
NMVOC											-38	-37	-39	-35	-31	-34				
MPI 2											-45	-40	-42	-43	-35	-37				

Ireland

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											88	75	74	102	148	110				
NO_2											16	2	-6	3	3	-4				
NMVOC											-41	-41	-65	-62	-65	-83				
MPI 2											52	38	34	52	75	53				

Italy

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											-24	-18	-13	-24	-31	-25				
NO_2											41	64	62	32	2	8				
NMVOC											-13	-15	-21	-40	-26	-32				
MPI 2											8	23	24	4	-14	-9				

Luxembourg

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											178	245	274	310	274	148				
NO_2											434	482	504	545	483	433				
NMVOC											249	573	851	1233	200	104				
MPI 2											306	364	389	427	378	290				

The Netherlands

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											-50	-52	-52	-49	-45	-40				
NO_2											40	39	35	29	33	29				
NMVOC											37	44	62	18	-2	109				
MPI 2											-5	-7	-8	-10	-6	-6				

Austria

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											-69	-76	-82	-84	-85	-78				
NO_2											-48	-57	-58	-61	-62	-57				
NMVOC											-44	-49	-49	-48	-79	-75				
MPI 2											-58	-67	-70	-73	-73	-68				

Portugal

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											209	184	227	227	263	343				
NO_2											86	78	98	118	132	133				
NMVOC											1227	1180	1182	1316	1367	1225				
MPI 2											147	131	163	173	197	238				

Finland

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											116	28	-20	-41	-31	-47				
NO_2											12	7	53	41	37	18				
NMVOC																				
MPI 2											64	17	17	0	3	-15				

Sweden

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											-79	-80	-83	-79	-80	-81				
NO_2											-49	-49	-54	-50	-56	-59				
NMVOC											148	156	185	198	143	120				
MPI 2											-64	-64	-68	-64	-68	-70				

United Kingdom

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO_2											4	17	37	54	47	19				
NO_2											9	-2	-2	4	14	5				
NMVOC											-50	-54	-56	-53	-50	-49				
MPI 2											6	8	18	29	30	12				

Note: **MPI 2 based on SO_2 and NO_2 emissions by combustion in manufacturing sector**

Emission data from EMEP (2002, es/gr/pt: 2000)
GDP data from Eurostat (2001)

Data on the GDP share of the manufactoring sector:
All countries except Ireland and Luxembourg: OECD (2000)
Ireland-- Central Statistics Office, Ireland (2001)
Luxembourg-- Eurostat (2001)

Appendix 2: Regression variables

Table 32 Taxes on production and imports

Taxes on Production and Imports / GDP

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	12.36	12.45	12.68	12.83	12.45	12.20	11.87	12.30	12.12	12.15	12.23	12.13	12.13	12.41	12.73	12.30	12.68	12.81	12.86	12.91
dk	18.62	18.41	17.66	17.84	18.08	18.36	19.64	19.43	19.26	18.29	17.60	17.27	17.14	17.44	17.96	17.79	18.09	18.43	18.92	18.90
de	13.17	12.94	12.72	12.87	12.94	12.66	12.29	12.36	12.29	12.51	12.46	12.56	12.66	12.95	13.34	13.00	12.76	12.69	12.61	12.90
gr	10.27	10.73	11.82	12.57	12.63	12.77	13.98	14.57	13.68	12.37	14.04	14.76	15.53	14.90	14.46	14.34	14.56	14.52	14.51	14.24
es	6.56	7.19	7.61	8.29	8.77	9.38	10.47	10.50	10.63	10.59	10.39	10.43	10.96	10.26	10.66	10.46	10.57	10.91	11.57	11.80
fr	15.26	15.17	15.44	15.47	15.78	15.80	15.50	15.67	15.57	15.18	15.13	14.72	14.56	14.70	15.00	15.16	15.61	15.78	15.60	15.51
ie	16.78	17.44	18.11	18.91	18.98	18.38	17.81	17.43	17.32	17.12	16.15	15.72	15.53	14.70	15.34	14.81	14.75	14.65	14.17	13.96
it	9.30	8.97	9.26	9.83	9.98	9.58	9.92	10.29	10.81	11.11	11.36	11.95	11.90	12.78	12.46	12.49	12.47	12.74	15.51	15.58
lu	14.31	14.53	15.19	17.25	16.85	13.65	13.14	13.16	13.07	12.90	13.10	13.06	13.86	14.18	14.30	13.94	14.26	14.26	13.92	14.02
nl	12.06	11.61	11.74	11.82	12.15	12.13	12.64	13.30	13.23	12.44	12.35	12.40	12.75	12.92	12.92	12.85	13.23	13.48	13.65	13.78
at	16.02	16.12	15.93	15.93	16.64	16.50	16.26	16.41	16.28	16.19	15.87	15.72	15.84	16.00	15.93	15.78	16.04	16.37	16.19	16.05
pt	11.89	12.12	12.63	13.23	13.13	12.81	14.94	14.56	15.21	14.41	14.37	14.35	15.21	14.38	15.08	14.95	15.02	14.95	15.49	15.29
fi	13.37	13.65	13.59	13.57	14.24	14.37	14.74	14.83	15.35	15.52	15.14	15.22	15.03	14.83	14.52	13.95	14.50	14.64	14.53	14.70
se	13.45	14.23	14.03	15.20	15.77	16.45	16.78	17.28	16.40	16.21	17.16	17.74	16.31	15.62	14.94	14.37	16.54	16.31	16.67	17.52
uk	15.48	16.44	16.40	15.96	15.88	15.52	16.02	16.05	13.41	12.92	12.82	13.54	13.36	13.22	13.23	13.54	13.59	13.68	13.89	13.90

Data Source: **Eurostat, New Cronos Database, 2001**

Table 33 *Fuel price*

Price of High Sulphur Fuel Oil for Industrial Customers, US$ at 1995 prices

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	164.6	186.6	194.3	181.5	193.0	179.3	109.6	110.1	92.4	105.8	115.7	118.9	121.6	130.2	130.6	125.4	136.3	137.4	123.9	132.3
dk	195.1	231.1	217.0	201.2	199.9	174.7	103.1	96.4	84.0	84.3	82.9	101.4	102.8	116.6	111.6	111.1	125.3	133.6	134.3	147.3
de	184.2	215.6	202.6	188.8	193.8	193.1	116.7	109.2	96.4	107.3	110.7	117.2	110.0	108.6	111.8	108.0	118.6	119.8	107.3	120.7
gr	260.0	292.5	269.1	268.6	279.3	291.8	263.0	224.5	197.3	177.5	179.5	203.3	221.2	215.1	210.5	209.1	223.6	219.9	193.1	208.4
es	194.8	274.4	261.4	280.0	266.9	264.3	194.5	162.6	154.4	150.9	159.5	173.3	173.7	184.3	182.6	178.5	194.4	198.4	183.6	196.6
fr	174.6	201.1	204.2	208.5	209.9	201.3	138.1	129.7	109.6	112.3	113.1	111.6	107.4	114.9	118.6	112.1	127.2	132.1	124.3	135.4
ie	289.4	316.1	307.0	304.6	302.1	302.6	209.2	209.8	173.5	179.1	180.8	180.4	169.1	168.1	170.3	168.3	238.4	207.3	172.6	175.8
it	190.0	218.0	205.6	205.3	211.8	200.9	120.9	129.9	123.5	137.6	165.1	180.4	176.1	184.3	180.9	183.0	190.9	188.6	177.7	194.6
lu	213.2	201.9	194.3	195.8	202.8	196.5	117.7	125.1	100.9	107.5	110.0	111.4	120.8	132.3	136.9	133.9	151.7	154.4	138.7	152.1
nl	134.1	146.1	157.1	140.8	148.7	139.0	94.6	101.3	91.5	95.6	112.6	116.6	115.1	153.5	157.3	152.7	164.3	142.4	139.3	148.3
at	165.4	202.6	189.4	174.4	181.2	179.3	136.5	108.4	102.5	97.5	101.8	101.3	96.2	96.6	90.5	99.6	105.2	106.9	99.1	99.5
pt	272.8	309.0	361.2	380.3	394.2	396.2	298.7	251.5	246.1	232.7	228.1	234.6	235.5	235.9	227.4	217.3	215.5	218.5	216.1	214.2
fi	120.7	133.7	129.1	128.2	128.9	128.8	87.2	88.3	87.1	93.2	107.4	106.8	102.9	109.0	92.8	88.5	95.9	97.3	94.5	105.0
se	220.4	254.1	278.7	277.8	295.6	292.6	184.0	194.8	168.7	188.3	207.7	209.6	191.0	157.3	160.3	147.0	159.4	166.1	152.5	162.3
uk	243.2	257.7	251.7	241.2	244.3	232.7	157.3	147.8	126.1	128.8	135.6	132.4	126.9	131.1	133.2	136.5	144.5	151.6	150.3	164.3

Data Source: **International Energy Agency, Fuel Prices Database, April 2001 / July 2002**

Table 34 Labour productivity of the manufacturing Sector

Labour Productivity, Manufacturing Sector (Thousand € at current prices)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	29.1	30.5	31.8	33.1	34.5	35.0	37.4	39.2	39.6	43.6	41.5	42.7	44.6	45.8	48.1	49.3	51.2	51.9	53.2	54.5
dk	24.7	26.5	28.3	30.2	32.0	32.9	34.9	37.3	41.9	42.2	42.1	44.2	47.1	47.6	49.5	52.7	53.9	55.7	57.5	59.4
de	23.8	25.2	26.6	28.1	29.5	31.9	32.8	34.3	35.9	36.2	37.0	38.1	38.7	40.1	44.4	46.5	48.5	47.9	49.4	50.8
gr	13.9	14.0	14.1	14.1	14.2	14.8	17.7	13.7	14.7	13.5	13.5	10.9	14.7	15.5	16.5	17.3	15.3	15.4	15.5	15.6
es	16.1	17.4	18.6	19.9	21.2	22.0	24.1	26.0	26.4	27.6	28.1	29.3	30.6	31.7	33.9	36.6	36.3	37.6	38.9	40.1
fr	28.2	29.5	30.8	32.1	33.4	33.4	35.7	38.2	40.4	40.9	41.3	41.6	42.4	43.0	46.9	48.1	49.6	50.2	51.5	52.8
ie	40.2	41.6	42.9	44.3	45.6	45.0	47.1	53.1	54.7	54.0	53.1	50.1	53.2	57.3	60.2	63.1	61.8	63.2	64.5	65.9
it	27.0	29.0	31.0	32.9	34.9	36.4	39.6	43.1	46.2	44.3	44.4	46.2	47.1	49.5	55.7	62.5	58.7	60.7	62.6	64.6
lu	31.2	33.0	34.8	36.6	38.4	37.3	41.6	42.2	48.0	53.1	51.1	47.6	51.1	55.8	60.5	57.2	57.5	62.1	63.9	65.7
nl	31.7	32.9	34.1	35.3	36.5	36.5	38.8	40.5	43.9	44.4	43.8	43.4	44.0	45.4	50.9	50.9	51.2	52.4	53.6	54.8
at	17.6	19.3	21.1	22.8	24.5	27.8	27.8	28.3	30.9	33.1	35.2	36.8	37.8	38.6	41.3	45.2	45.1	46.8	48.6	50.3
pt	9.3	9.5	9.8	10.0	10.3	9.8	10.7	11.9	12.7	12.4	10.6	11.4	12.0	12.6	12.7	13.9	13.4	13.7	14.0	14.2
fi	25.1	27.7	30.2	32.7	35.2	37.8	40.7	46.3	46.2	49.0	49.2	44.8	51.2	59.8	64.7	64.9	65.6	68.1	70.6	73.1
se	13.4	16.6	19.7	22.8	25.9	34.4	34.9	36.5	37.6	37.0	41.6	42.5	44.5	54.0	59.9	64.6	66.7	66.5	69.6	72.7
uk	25.1	25.9	26.7	27.5	28.3	27.2	29.2	31.4	33.5	34.2	33.8	32.4	33.9	35.5	37.0	36.9	37.5	38.8	39.6	40.4

Note: **Data in grey cells was extrapolated by linear projection**
Original data label "Labour productivity, level (at market exchange rate)"

Data Source: **Eurostat, New Cronos Database, 2001**

Table 35 Pollution performance

Refer to GPI 3 indicator (table 30)

Table 36 Chemical industry production value at 1995 prices

Chemical Industry Production Value at 1995 prices, millions of 1995 US$

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	12957	13080	13345	13897	14878	15389	15737	17004	18496	19211	20437	20682	22930	22011	21949	23646	24463	27888	27418	29120
dk	1849	2012	2090	2071	2237	2367	2516	2367	2533	2604	2625	2649	2814	2861	3203	3523	3649	4169	4269	4846
de	59869	59505	56959	61106	64379	65325	64816	66416	70053	70926	72739	73763	74927	72236	76455	76528	77692	81983	80760	85526
gr	1705	1668	1670	1797	1942	2074	1970	1984	2134	2258	2307	2191	2113	2201	2231	2475	2662	2781	2137	2321
es	15694	16021	15294	15421	16203	16585	16857	17130	17421	18185	18185	18203	18130	17858	20385	20913	20967	22497	23036	25051
fr	32708	33316	34001	35903	37728	38962	39282	40515	42845	45129	45677	46408	48829	49377	52665	53305	54812	58797	59116	64413
ie	828	952	911	1089	1205	1376	1374	1487	1707	1992	2050	2497	2929	3214	3843	4456	5284	10208	12587	19206
it	27125	26252	26217	27125	28801	29918	30441	31628	33653	34281	34910	34107	34805	33932	35084	36167	36935	38351	37714	40197
lu																				
nl	10742	11495	11145	12932	14106	15210	15140	15420	16524	17120	17521	16978	17080	17256	19107	20474	20382	21945	22131	23367
at	2041	2058	1983	2161	2504	2400	2631	2455	2734	2835	2878	3022	2915	2818	3036	3278	3514	3628	3702	4083
pt	1730	1698	1891	1823	1936	3295	3403	3617	3641	3778	4032	3565	3307	2964	3004	2948	2992	3087	2977	3136
fi	2460	2529	2430	2612	2744	2830	2817	2992	3220	3402	3306	3134	3180	3266	3584	3683	3706	3824	3786	4132
se	3508	3534	3570	3845	3960	4001	3873	4303	4582	4551	4467	5075	5611	5933	5875	6085	6531	6994	7143	7776
uk	23447	23419	23587	25349	26972	27979	28467	30839	32432	33957	33889	34838	35922	36736	38633	39616	40463	40236	39648	41138

Data source: **1980-1996: extrapolated from an production index (CEFIC, ESCIMO Database 2001)**
1997-1999: CEFIC Facts &Figures 1998, 1999, 2000

Table 37 Chemical industry production value / GDP at 1995 prices

Chemical Industry Production Value at 1995 prices / GDP at 1995 prices

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	6.3%	8.4%	10.4%	11.9%	13.9%	14.2%	10.6%	9.4%	9.8%	10.4%	9.2%	9.4%	9.5%	9.9%	9.2%	8.6%	9.3%	11.9%	11.5%	12.5%
dk	1.6%	2.2%	2.5%	2.5%	2.9%	3.0%	2.3%	1.8%	1.9%	2.0%	1.7%	1.8%	1.8%	2.0%	2.1%	1.9%	2.0%	2.6%	2.6%	2.9%
de	4.3%	5.6%	5.9%	6.6%	7.6%	7.9%	5.6%	4.7%	4.8%	5.1%	4.3%	3.9%	3.6%	3.6%	3.6%	3.2%	3.4%	4.0%	3.9%	4.3%
gr	2.0%	2.4%	2.4%	3.0%	3.5%	3.8%	3.2%	2.8%	2.7%	2.9%	2.5%	2.2%	2.0%	2.3%	2.2%	2.1%	2.2%	2.4%	1.8%	2.0%
es	4.3%	5.5%	5.7%	6.8%	7.4%	7.5%	5.6%	4.6%	4.1%	4.1%	3.3%	3.1%	2.9%	3.6%	4.1%	3.7%	3.7%	4.2%	4.1%	4.5%
fr	2.9%	3.6%	4.2%	4.8%	5.5%	5.6%	4.1%	3.6%	3.6%	4.0%	3.4%	3.5%	3.5%	3.8%	3.9%	3.5%	3.6%	4.3%	4.3%	4.8%
ie	2.4%	3.2%	3.1%	4.0%	4.7%	5.3%	4.0%	3.8%	4.0%	4.7%	4.0%	4.9%	5.2%	6.3%	6.9%	6.8%	7.5%	13.2%	15.3%	21.9%
it	3.5%	4.1%	4.4%	4.6%	5.1%	5.3%	3.9%	3.3%	3.3%	3.3%	2.8%	2.7%	2.7%	3.3%	3.4%	3.3%	3.1%	3.4%	3.3%	3.6%
lu																				
nl	3.6%	5.1%	5.4%	6.7%	8.1%	8.9%	6.5%	5.6%	5.8%	6.4%	5.4%	5.3%	5.0%	5.3%	5.5%	5.1%	5.2%	6.0%	5.9%	6.3%
at	1.5%	1.9%	2.0%	2.2%	2.8%	2.7%	2.1%	1.6%	1.8%	1.9%	1.6%	1.7%	1.5%	1.5%	1.5%	1.4%	1.6%	1.8%	1.8%	2.1%
pt	3.5%	3.9%	4.8%	5.4%	6.4%	10.4%	7.7%	6.8%	6.0%	6.0%	5.1%	4.2%	3.3%	3.4%	3.3%	2.8%	2.8%	3.0%	2.8%	2.9%
fi	2.8%	3.2%	3.2%	3.8%	3.9%	4.0%	3.1%	2.7%	2.5%	2.5%	2.2%	2.4%	2.8%	3.7%	3.6%	2.9%	3.0%	3.2%	3.1%	3.4%
se	1.6%	2.0%	2.4%	2.9%	3.0%	3.0%	2.2%	2.1%	2.1%	2.0%	1.7%	1.9%	2.1%	3.1%	2.9%	2.6%	2.6%	3.0%	3.1%	3.4%
uk	2.5%	2.9%	3.3%	3.9%	4.5%	4.6%	3.9%	3.5%	3.2%	3.4%	3.1%	3.1%	3.2%	3.7%	3.7%	3.6%	3.6%	3.2%	3.0%	3.0%

Data Sources:	**Production**	**1980-1996: extrapolated from an production index (CEFIC, ESCIMO Database 2001)**
		1997-1999: CEFIC Facts &Figures 1998, 1999, 2000
	GDP	**1980-1996: OECD National Accounts/main aggregates 1960-1997 (1999)**
		1997-1999: World Bank, Word Development Indicators (2002)

Table 38 Chemical industry employees (absolute terms)

Chemical Industry Employees (thousands)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	89.9	88.3	87.8	87.6	88.6	89.6	90.6	90.7	92.4	95.3	96.2	98.9	98.5	97.4	94.2	93.1	92.7	93.7	95.0	97.2
dk	22.6	22.6	23.4	22.6	24.2	25.3	25.7	26.2	51.2	51.7	52.1	52.8	52.9	52.3	51.7	54.2	54.7	57.1	58.9	65.6
de	568.0	565.0	559.0	549.0	550.0	557.0	567.1	571.8	575.3	582.0	591.9	716.7	654.8	608.7	570.0	535.9	517.5	500.5	484.6	556.4
gr	19.7	19.8	20.5	19.8	20.3	20.5	20.1	19.6	19.9	20.6	20.6	20.0	18.6	19.1	19.2	19.2	19.0	18.6	17.5	18.6
es	139.1	135.6	132.5	134.1	133.7	130.5	132.7	129.3	129.3	135.7	133.9	133.3	131.0	124.9	121.8	120.2	120.8	122.5	121.4	120.8
fr	297.4	285.1	280.4	275.2	274.0	272.3	269.3	267.6	265.6	264.4	266.4	263.3	259.5	249.7	250.1	246.3	242.9	242.1	236.5	236.0
ie	12.4	12.3	11.5	11.8	11.7	11.7	12.0	12.2	12.2	12.9	13.8	15.0	15.3	15.9	16.5	18.3	19.7	21.0	18.9	19.4
it	283.0	271.0	263.0	251.0	241.0	233.0	230.0	225.0	222.5	220.0	217.0	215.0	207.5	200.0	193.0	191.0	189.7	189.0	188.4	172.7
lu																				
nl	89.9	90.5	88.5	86.7	86.9	89.7	91.1	91.8	93.5	93.6	94.0	93.5	91.2	84.8	81.8	80.4	78.6	79.0	79.1	81.7
at	62.2	60.0	56.2	56.5	56.5	56.3	55.4	54.8	55.8	56.8	56.6	54.1	52.2	49.9	49.1	48.8	45.0	44.0	42.0	44.4
pt	36.5	37.0	36.4	35.2	33.6	37.3	36.7	39.1	37.8	33.4	30.2	28.3	30.0	27.6	26.4	26.4	25.7	24.5	27.2	24.4
fi	24.3	24.9	24.5	25.0	24.8	24.6	24.2	25.2	20.3	19.9	19.7	19.0	18.7	18.2	17.7	18.0	18.0	18.1	18.0	16.1
se	45.2	43.8	43.2	43.0	43.6	42.7	43.6	44.0	42.8	42.0	41.7	39.7	37.0	31.5	31.9	33.5	35.5	35.5	34.5	32.6
uk	401.8	365.5	350.3	330.2	329.1	324.4	314.8	308.7	314.4	318.5	303.6	278.2	267.8	257.9	250.6	255.6	249.7	242.4	251.6	224.3

Data source: **Chemical industry employees:** **CEFIC, ESCIMO Database (2001)**

Table 39 Chemical industry employees / total workforce

Chemical Industry Employees / Total Workforce

YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be	2.43%	2.43%	2.45%	2.47%	2.50%	2.52%	2.53%	2.52%	2.53%	2.57%	2.56%	2.62%	2.62%	2.62%	2.56%	2.52%	2.50%	2.51%	2.51%	2.56%
dk	0.93%	0.94%	0.97%	0.93%	0.98%	1.00%	0.99%	1.00%	1.94%	1.97%	2.00%	2.04%	2.06%	2.07%	2.05%	2.12%	2.11%	2.16%	2.18%	2.40%
de	2.11%	2.10%	2.10%	2.09%	2.09%	2.10%	2.11%	2.11%	2.11%	2.10%	2.08%	1.96%	1.83%	1.73%	1.63%	1.54%	1.50%	1.47%	1.43%	1.64%
gr	0.57%	0.55%	0.57%	0.55%	0.56%	0.56%	0.55%	0.54%	0.54%	0.56%	0.55%	0.54%	0.50%	0.51%	0.50%	0.50%	0.49%	0.48%	0.45%	0.47%
es	1.19%	1.19%	1.18%	1.20%	1.22%	1.17%	1.09%	1.01%	0.98%	0.99%	0.94%	0.92%	0.92%	0.90%	0.88%	0.85%	0.84%	0.83%	0.79%	0.77%
fr	1.36%	1.31%	1.28%	1.26%	1.26%	1.26%	1.24%	1.23%	1.21%	1.19%	1.19%	1.17%	1.16%	1.13%	1.13%	1.11%	1.09%	1.08%	1.04%	1.03%
ie	1.06%	1.07%	1.00%	1.04%	1.05%	1.08%	1.10%	1.10%	1.10%	1.16%	1.19%	1.30%	1.32%	1.35%	1.36%	1.44%	1.48%	1.55%	1.32%	1.29%
it	1.28%	1.23%	1.19%	1.12%	1.08%	1.03%	1.01%	0.98%	0.96%	0.95%	0.93%	0.91%	0.89%	0.88%	0.87%	0.86%	0.85%	0.85%	0.84%	0.77%
lu																				
nl	1.83%	1.87%	1.87%	1.87%	1.87%	1.90%	1.89%	1.87%	1.87%	1.84%	1.81%	1.77%	1.71%	1.59%	1.54%	1.49%	1.43%	1.40%	1.37%	1.40%
at	1.90%	1.84%	1.74%	1.77%	1.77%	1.76%	1.73%	1.71%	1.74%	1.74%	1.70%	1.60%	1.54%	1.48%	1.45%	1.45%	1.34%	1.31%	1.24%	1.31%
pt	0.82%	0.83%	0.83%	0.81%	0.79%	0.87%	0.88%	0.91%	0.86%	0.75%	0.67%	0.61%	0.65%	0.61%	0.59%	0.59%	0.58%	0.54%	0.58%	0.52%
fi	1.08%	1.09%	1.06%	1.08%	1.06%	1.06%	1.04%	1.08%	0.86%	0.84%	0.84%	0.85%	0.90%	0.94%	0.92%	0.92%	0.92%	0.90%	0.87%	0.77%
se	1.07%	1.03%	1.02%	1.01%	1.02%	0.99%	1.00%	1.00%	0.96%	0.92%	0.92%	0.89%	0.86%	0.78%	0.79%	0.82%	0.87%	0.88%	0.85%	0.79%
uk	1.58%	1.50%	1.46%	1.40%	1.36%	1.32%	1.28%	1.23%	1.22%	1.20%	1.13%	1.07%	1.05%	1.03%	0.99%	1.00%	0.97%	0.90%	0.93%	0.82%

Data sources:	**Chemical industry employees:**	**CEFIC, ESCIMO Database (2001)**
	Total occupied population (1980-1997):	**Eurostat, New Cronos Database (2001)**
	Total occupied population (1998-1999):	**Linear projection of Eurostat data**

Table 40 Chemical industry intra-EU exports (absolute)

Intra-EU Chemical Exports (million €)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be											12338.8	12731.7	13098.5	14401.9	17402.8	20831.5	22086.6	19789.1	27101.1	
dk											1081.9	1150.8	1356.9	1330.4	2001.4	2297.0	2231.1	2626.0	2676.1	
de											22518.5	22625.6	22906.3	21052.9	24809.0	31503.8	30986.6	32954.4	33352.6	
gr											173.1	171.7	180.6	171.9	179.2	242.3	209.2	199.2	215.5	
es											2521.4	2566.2	2547.0	2449.2	3273.0	3880.2	4432.8	4917.6	5383.7	
fr											12783.5	13367.5	13897.7	13753.5	15875.0	19701.0	20105.1	22126.7	24147.6	
it											5453.8	5416.6	5858.4	5769.7	6524.9	7718.5	8474.6	9516.3	9970.6	
ie											1886.1	2203.6	2675.9	2776.5	3739.2	4324.5	5512.0	7597.5	8204.3	
lu																				
nl											13948.2	13565.0	13316.8	12049.0	13998.1	16520.7	18102.4	19565.7	19872.0	
at											1575.6	1754.4	1747.6	1751.6	1978.3	2426.2	2481.3	2675.1	2804.4	
pt											462.7	430.0	419.8	399.4	532.2	640.5	618.0	735.4	758.2	
fi											534.7	546.1	571.7	574.0	718.6	1086.2	1037.2	1179.6	1289.2	
se											1795.2	2069.4	2244.4	2346.8	2707.1	2862.9	3073.0	3283.2	3493.3	
uk											10666.1	11377.0	11501.0	12032.0	13752.8	15645.8	16487.5	18501.2	19494.0	

Data source **CEFIC, ESCIMO Database (2001)**
Note: **Projected data points are marked in grey**

Table 41 Chemical industry intra-EU exports / GDP

Chemical Industry Intra-EU Exports / GDP

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
be											4.28%	4.47%	4.21%	4.98%	5.67%	5.88%	6.49%	6.51%	8.79%	
dk											0.55%	0.61%	0.67%	0.71%	1.00%	0.98%	0.96%	1.25%	1.24%	
de											1.02%	0.93%	0.84%	0.81%	0.91%	1.01%	1.04%	1.25%	1.26%	
gr											0.14%	0.14%	0.13%	0.14%	0.14%	0.16%	0.13%	0.13%	0.14%	
es											0.35%	0.34%	0.32%	0.38%	0.51%	0.54%	0.60%	0.70%	0.75%	
fr											0.73%	0.79%	0.76%	0.81%	0.90%	0.99%	1.03%	1.26%	1.35%	
it											0.34%	0.33%	0.35%	0.43%	0.49%	0.55%	0.55%	0.65%	0.68%	
ie											2.82%	3.37%	3.69%	4.18%	5.19%	5.09%	6.03%	7.62%	7.72%	
lu																				
nl											3.35%	3.30%	2.99%	2.85%	3.14%	3.20%	3.59%	4.17%	4.12%	
at											0.67%	0.74%	0.67%	0.71%	0.76%	0.81%	0.85%	1.04%	1.08%	
pt											0.46%	0.39%	0.32%	0.35%	0.46%	0.47%	0.45%	0.55%	0.55%	
fi											0.27%	0.32%	0.39%	0.50%	0.56%	0.67%	0.65%	0.77%	0.81%	
se											0.53%	0.61%	0.66%	0.94%	1.03%	0.96%	0.96%	1.10%	1.18%	
uk											0.74%	0.79%	0.79%	0.94%	1.02%	1.09%	1.13%	1.13%	1.12%	

Data source **Exports:** **CEFIC, ESCIMO Database (2001)**
GDP: **1980-1996: OECD National Accounts/main aggregates 1960-1997 (1999)**
1997-1999: World Bank, Word Development Indicators (2002)

Note: **Chemical Industry intra-EU exports in US\$ at 1995 exchange rates/GDP at 1995 constant prices, millions of US\$**
Projected data points are marked in grey

Appendix 3: Regression Results

Table 42 Regression models on CI production / GDP, Ireland included

Fixed effects model

Dependent variable: prod_r
Dataset includes Ireland

xtreg prod_r tax fpr m_prod gdp gpi3 year2-year20, fe

Fixed-effects (within) regression			Number of obs =	280	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.5826	Obs per group:	min =	20
	between =	0.2576		avg =	20
	overall =	0.3245		max =	20
			F(24,243) =	14.75	
corr(u_i, Xb) =		-0.2837	Prob > F =	0.0000	

prod_r	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Int.]
tax	-1.7294	0.1654	-10.4500	0.0000	-2.0553	-1.4035
fpr	0.5818	0.1120	5.2000	0.0000	0.3612	0.8024
m_prod	0.3145	0.1098	2.8600	0.0050	0.0982	0.5308
gpi3	0.2567	0.0825	3.1100	0.0020	0.0943	0.4191
year2	0.1470	0.0688	2.1400	0.0330	0.0116	0.2825
year3	0.2490	0.0695	3.5800	0.0000	0.1121	0.3858
year4	0.4382	0.0703	6.2300	0.0000	0.2998	0.5767
year5	0.5776	0.0723	7.9900	0.0000	0.4351	0.7201
year6	0.6445	0.0736	8.7500	0.0000	0.4994	0.7895
year7	0.6239	0.0838	7.4400	0.0000	0.4588	0.7890
year8	0.5155	0.0891	5.7900	0.0000	0.3401	0.6910
year9	0.5245	0.0963	5.4500	0.0000	0.3348	0.7141
year10	0.5212	0.0938	5.5600	0.0000	0.3364	0.7060
year11	0.3425	0.0901	3.8000	0.0000	0.1651	0.5199
year12	0.3356	0.0885	3.7900	0.0000	0.1612	0.5099
year13	0.3031	0.0930	3.2600	0.0010	0.1200	0.4862
year14	0.3769	0.0949	3.9700	0.0000	0.1901	0.5638
year15	0.3878	0.1005	3.8600	0.0000	0.1899	0.5858
year16	0.2769	0.1039	2.6700	0.0080	0.0723	0.4815
year17	0.2841	0.1022	2.7800	0.0060	0.0829	0.4854
year18	0.4467	0.1040	4.2900	0.0000	0.2417	0.6516
year19	0.4860	0.1087	4.4700	0.0000	0.2719	0.7002
year20	0.5513	0.1089	5.0600	0.0000	0.3369	0.7658
_cons	-4.3992	0.8010	-5.4900	0.0000	-5.9770	-2.8214
sigma_u	0.41268					
sigma_e	0.176188					
rho	0.845827 (fraction of variance due to u_i)					

F test that all u_i=0: F(13, 243) = 88.76 Prob > F = 0.0000

Random effects model

Dependent variable: prod_r
Dataset includes Ireland

xtreg prod_r tax fpr m_prod gdp gpi3 year2-year20, re

Random-effects GLS regression			Number of obs =	280	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.5822	Obs per group:	min =	20
	between =	0.2711		avg =	20
	overall =	0.338		max =	20
Random effects u_i ~ Gaussian			Wald chi2(23) =	344.52	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

prod_r	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Int.]
tax	-1.6833	0.1589	-10.5900	0.0000	-1.9948	-1.3718
fpr	0.5439	0.1076	5.0500	0.0000	0.3329	0.7548
m_prod	0.3346	0.1044	3.2100	0.0010	0.1300	0.5391
gpi3	0.2443	0.0794	3.0700	0.0020	0.0886	0.4000
year2	0.1504	0.0684	2.2000	0.0280	0.0163	0.2844
year3	0.2501	0.0690	3.6200	0.0000	0.1148	0.3854
year4	0.4362	0.0698	6.2500	0.0000	0.2994	0.5731
year5	0.5746	0.0717	8.0100	0.0000	0.4340	0.7151
year6	0.6396	0.0729	8.7800	0.0000	0.4968	0.7824
year7	0.6018	0.0819	7.3500	0.0000	0.4413	0.7622
year8	0.4899	0.0867	5.6500	0.0000	0.3200	0.6597
year9	0.4943	0.0933	5.3000	0.0000	0.3114	0.6771
year10	0.4928	0.0910	5.4200	0.0000	0.3145	0.6712
year11	0.3156	0.0874	3.6100	0.0000	0.1442	0.4870
year12	0.3104	0.0860	3.6100	0.0000	0.1417	0.4790
year13	0.2758	0.0901	3.0600	0.0020	0.0992	0.4525
year14	0.3505	0.0919	3.8100	0.0000	0.1704	0.5307
year15	0.3592	0.0971	3.7000	0.0000	0.1689	0.5496
year16	0.2472	0.1002	2.4700	0.0140	0.0507	0.4436
year17	0.2573	0.0987	2.6100	0.0090	0.0637	0.4508
year18	0.4190	0.1005	4.1700	0.0000	0.2221	0.6159
year19	0.4543	0.1047	4.3400	0.0000	0.2490	0.6596
year20	0.5214	0.1049	4.9700	0.0000	0.3157	0.7271
_cons	-4.3202	0.7853	-5.5000	0.0000	-5.8594	-2.7809
sigma_u	0.441206					
sigma_e	0.176188					
rho	0.862465 (fraction of variance due to u_i)					

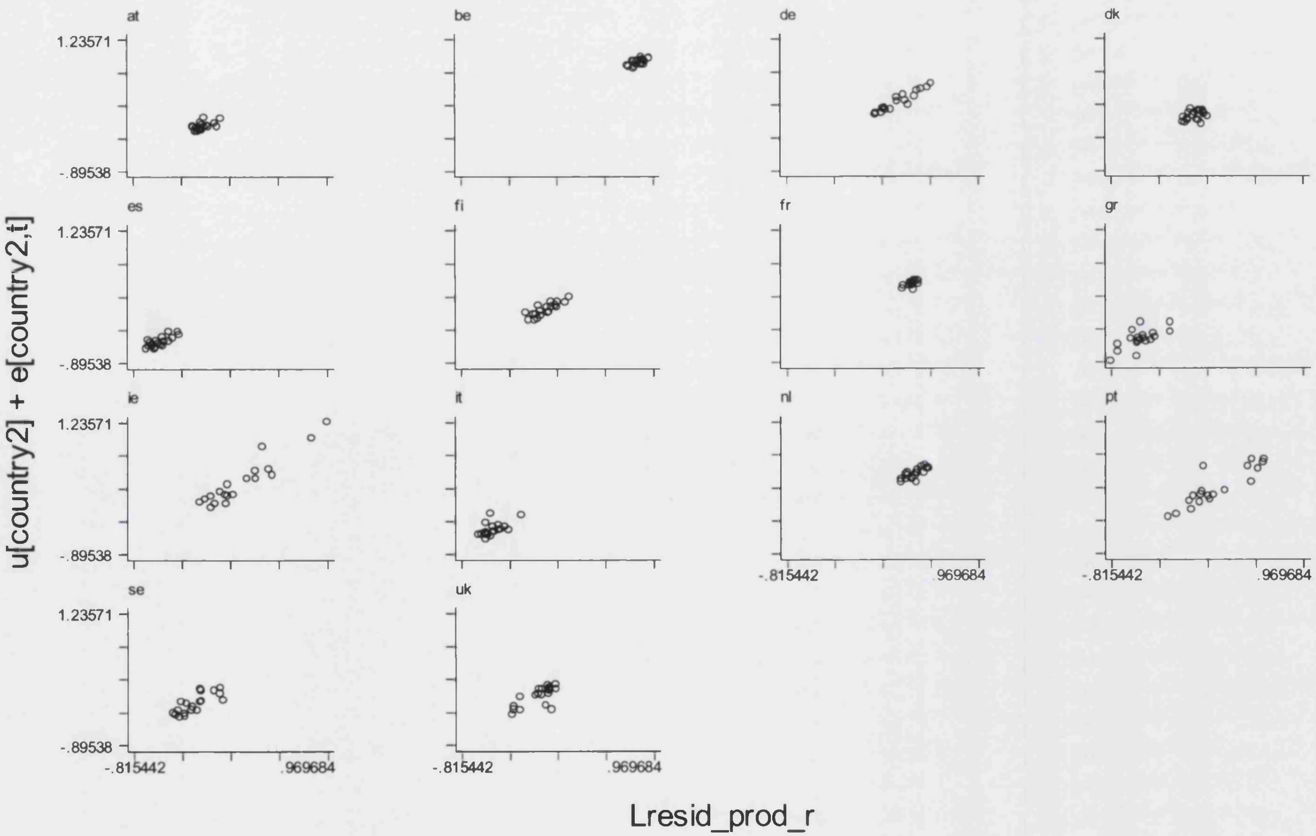
Hausman specification test

Test:	Ho: difference in coefficients not systematic
chi2(24) =	(b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
	= 1.88
Prob>chi2 =	1.0000
Result:	Ho cannot be rejected.
	Random effects model can be used safely.

prod_r	FE	RE	Difference
tax	-1.7294	-1.6833	-0.0461
fpr	0.5818	0.5439	0.0379
m_prod	0.3145	0.3346	-0.0201
gpi3	0.2567	0.2443	0.0124
year2	0.1470	0.1504	-0.0033
year3	0.2490	0.2501	-0.0012
year4	0.4382	0.4362	0.0020
year5	0.5776	0.5746	0.0030
year6	0.6445	0.6396	0.0049
year7	0.6239	0.6018	0.0221
year8	0.5155	0.4899	0.0257
year9	0.5245	0.4943	0.0302
year10	0.5212	0.4928	0.0284
year11	0.3425	0.3156	0.0269
year12	0.3356	0.3104	0.0252
year13	0.3031	0.2758	0.0273
year14	0.3769	0.3505	0.0264
year15	0.3878	0.3592	0.0286
year16	0.2769	0.2472	0.0298
year17	0.2841	0.2573	0.0268
year18	0.4467	0.4190	0.0277
year19	0.4860	0.4543	0.0317
year20	0.5513	0.5214	0.0300

Auto-correlation: graphical approximation

Production value / GDP: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

Dataset includes Ireland

prod_r[country2,t] = Xb + u[country2] + e[country2,t]

Test:	Var(u) =	0
	chi2(1) =	1726.62
	Prob > chi2 =	0.0000

Result: Within-unit correlation cannot be ruled out

Random effects model corrected for autocorrelation

Dependent variable: prod_r
Dataset includes Ireland

xtregar prod_r tax fpr m_prod gpi3 year2-year20

Random-effects GLS regression			Number of obs =	280	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.473	Obs per group:	min =	20
	between =	0.217		avg =	20
	overall =	0.2646		max =	20
			Wald chi2(24) =	604.71	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

prod_r	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.4314	0.1429	-3.0200	0.0030	-0.7115	-0.1513
fpr	0.0304	0.0806	0.3800	0.7060	-0.1275	0.1883
m_prod	0.0893	0.0925	0.9700	0.3340	-0.0920	0.2706
gpi3	0.2147	0.0572	3.7500	0.0000	0.1025	0.3269
year2	0.2183	0.0254	8.6100	0.0000	0.1686	0.2679
year3	0.3093	0.0342	9.0300	0.0000	0.2422	0.3764
year4	0.4619	0.0415	11.1400	0.0000	0.3806	0.5432
year5	0.6031	0.0482	12.5200	0.0000	0.5086	0.6975
year6	0.6665	0.0532	12.5300	0.0000	0.5623	0.7708
year7	0.4080	0.0664	6.1500	0.0000	0.2779	0.5381
year8	0.2638	0.0733	3.6000	0.0000	0.1201	0.4075
year9	0.2439	0.0813	3.0000	0.0030	0.0845	0.4033
year10	0.2871	0.0814	3.5300	0.0000	0.1275	0.4466
year11	0.1366	0.0806	1.6900	0.0900	-0.0214	0.2945
year12	0.1426	0.0806	1.7700	0.0770	-0.0153	0.3005
year13	0.1076	0.0857	1.2600	0.2090	-0.0604	0.2756
year14	0.2264	0.0886	2.5600	0.0110	0.0528	0.4000
year15	0.2351	0.0942	2.5000	0.0130	0.0504	0.4197
year16	0.1432	0.0982	1.4600	0.1440	-0.0491	0.3356
year17	0.1735	0.0969	1.7900	0.0740	-0.0166	0.3635
year18	0.3286	0.0992	3.3100	0.0010	0.1342	0.5230
year19	0.3092	0.1038	2.9800	0.0030	0.1058	0.5125
year20	0.4115	0.1044	3.9400	0.0000	0.2068	0.6161
_cons	-3.9102	0.5972	-6.5500	0.0000	-5.0807	-2.7397
rho_ar	0.92267 (estimated autocorrelation coefficient)					
sigma_u	0.33916					
sigma_e	0.07877					
rho_fov	0.94882 (fraction of variance due to u_i)					
theta	0.58700					

Heteroskedasticity: graphical approximation

Production value / GDP: Predicted values against residuals

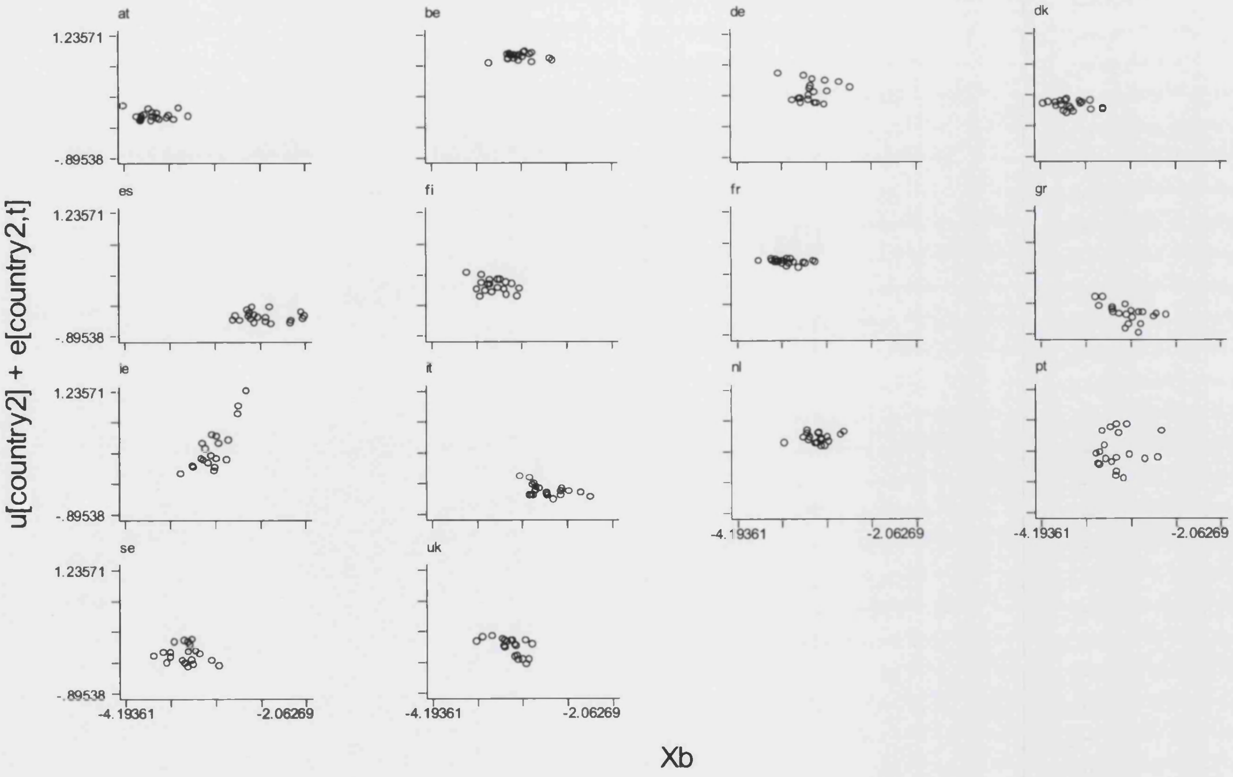


Table 43 Regression models on CI production / GDP, Ireland excluded

Fixed effects model

Dependent variable: prod_r
Dataset excludes Ireland

xtreg prod_r tax fpr m_prod gdp gpi3 year2-year20, fe

Fixed-effects (within) regression			Number of obs =	260	
Group variable (i) : *country2*			Number of groups =	13	
R-sq:	within =	0.6863	Obs per group:	min =	20
	between =	0.2604		avg =	20
	overall =	0.3434		max =	20
			F(13,224) =	21.31	
corr(u_i, Xb) =		0.0241	Prob > F =	0.0000	

prod_r	Coef.	Std.	Err.	t	P>|t|	[95% Conf. Int.]
tax	-0.9804	0.1381	-7.1000	0.0000	-1.2527	-0.7082
fpr	0.4990	0.0856	5.8300	0.0000	0.3304	0.6676
m_prod	0.3783	0.0822	4.6000	0.0000	0.2163	0.5402
gpi3	0.1256	0.0635	1.9800	0.0490	0.0006	0.2507
year2	0.1328	0.0530	2.5100	0.0130	0.0284	0.2372
year3	0.2229	0.0536	4.1600	0.0000	0.1172	0.3286
year4	0.3775	0.0543	6.9600	0.0000	0.2706	0.4845
year5	0.4996	0.0559	8.9400	0.0000	0.3894	0.6097
year6	0.5620	0.0570	9.8600	0.0000	0.4497	0.6742
year7	0.4889	0.0650	7.5200	0.0000	0.3608	0.6170
year8	0.3658	0.0692	5.2900	0.0000	0.2295	0.5021
year9	0.3627	0.0743	4.8800	0.0000	0.2163	0.5090
year10	0.3673	0.0722	5.0900	0.0000	0.2250	0.5096
year11	0.1863	0.0697	2.6700	0.0080	0.0490	0.3236
year12	0.1642	0.0686	2.3900	0.0170	0.0290	0.2993
year13	0.1174	0.0719	1.6300	0.1040	-0.0242	0.2590
year14	0.1984	0.0731	2.7100	0.0070	0.0544	0.3424
year15	0.1915	0.0773	2.4800	0.0140	0.0392	0.3438
year16	0.0811	0.0798	1.0200	0.3100	-0.0761	0.2384
year17	0.0891	0.0792	1.1300	0.2620	-0.0669	0.2452
year18	0.2086	0.0804	2.5900	0.0100	0.0502	0.3671
year19	0.2117	0.0841	2.5200	0.0130	0.0460	0.3775
year20	0.2568	0.0842	3.0500	0.0030	0.0908	0.4228
_cons	-5.4256	0.6006	-9.0300	0.0000	-6.6092	-4.2420
sigma_u	0.393214					
sigma_e	0.130592					
rho	0.900657 (fraction of variance due to u_i)					

F test that all u_i=0: F(12,224) = 164.23 Prob > F = 0.0000

Random effects model

Dependent variable: prod_r
Dataset excludes Ireland

xtreg prod_r tax fpr m_prod gdp gpi3 year2-year20, re

Random-effects GLS regression			Number of obs =	260	
Group variable (i) : *country2*			Number of groups =	13	
R-sq:	within =	0.6863	Obs per group:	min =	20
	between =	0.2632		avg =	20
	overall =	0.3456		max =	20
Random effects u_i ~ Gaussian			Wald chi2(23) =	498.52	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

prod_r	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.9840	0.1337	-7.3600	0.0000	-1.2460	-0.7219
fpr	0.4926	0.0832	5.9200	0.0000	0.3294	0.6557
m_prod	0.3825	0.0801	4.7800	0.0000	0.2255	0.5395
gpi3	0.1252	0.0621	2.0200	0.0440	0.0036	0.2468
year2	0.1335	0.0527	2.5300	0.0110	0.0303	0.2368
year3	0.2234	0.0533	4.1900	0.0000	0.1189	0.3279
year4	0.3777	0.0539	7.0000	0.0000	0.2720	0.4834
year5	0.4997	0.0555	9.0000	0.0000	0.3909	0.6086
year6	0.5617	0.0565	9.9400	0.0000	0.4509	0.6725
year7	0.4861	0.0638	7.6100	0.0000	0.3610	0.6112
year8	0.3624	0.0677	5.3500	0.0000	0.2296	0.4952
year9	0.3584	0.0726	4.9400	0.0000	0.2161	0.5006
year10	0.3630	0.0706	5.1400	0.0000	0.2246	0.5014
year11	0.1825	0.0682	2.6800	0.0070	0.0489	0.3161
year12	0.1607	0.0672	2.3900	0.0170	0.0290	0.2924
year13	0.1136	0.0703	1.6200	0.1060	-0.0242	0.2514
year14	0.1945	0.0716	2.7200	0.0070	0.0543	0.3348
year15	0.1873	0.0756	2.4800	0.0130	0.0391	0.3354
year16	0.0765	0.0780	0.9800	0.3260	-0.0763	0.2294
year17	0.0851	0.0775	1.1000	0.2720	-0.0668	0.2370
year18	0.2046	0.0787	2.6000	0.0090	0.0504	0.3588
year19	0.2073	0.0821	2.5200	0.0120	0.0464	0.3682
year20	0.2527	0.0824	3.0700	0.0020	0.0913	0.4141
_cons	-5.3939	0.6054	-8.9100	0.0000	-6.5804	-4.2073
sigma_u	0.437398					
sigma_e	0.130592					
rho	0.918154 (fraction of variance due to u_i)					

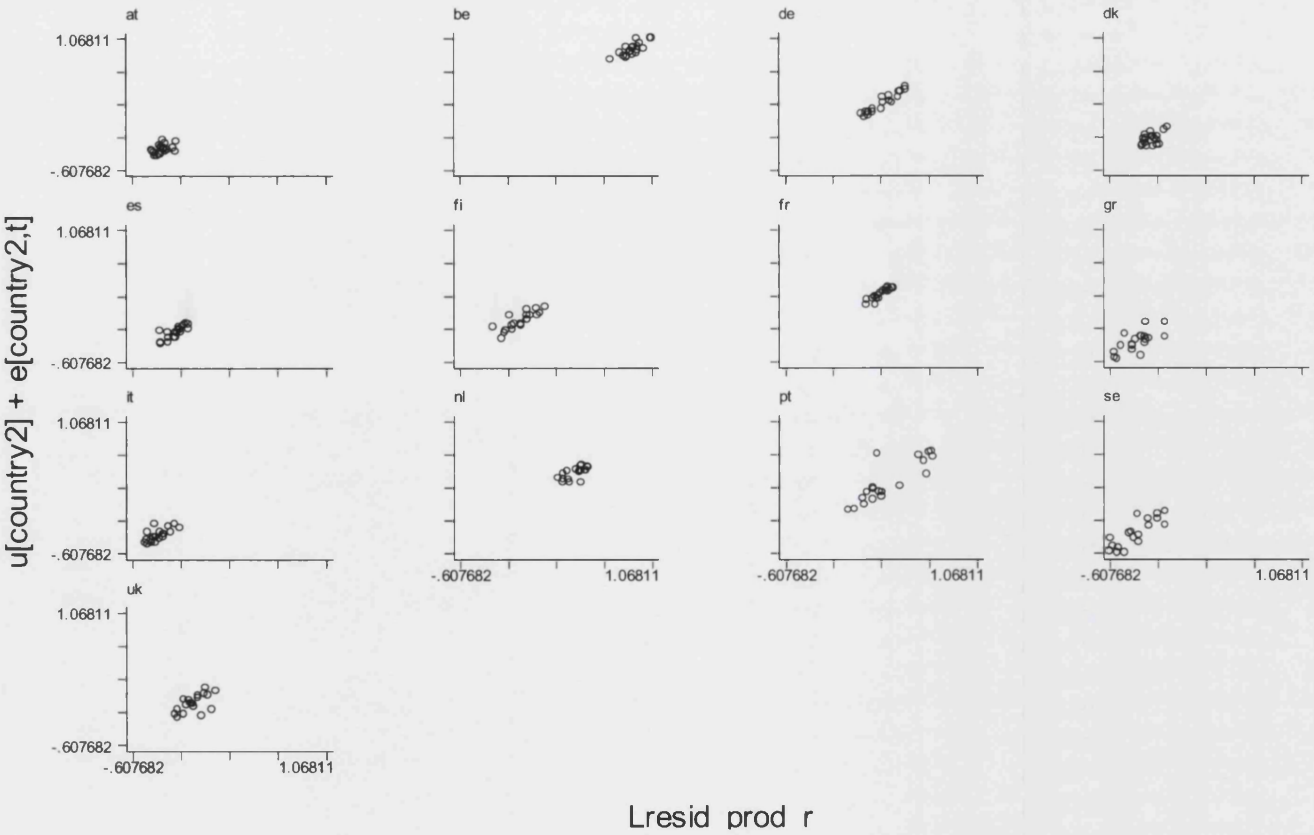
Hausman specification test

Test:	Ho: difference in coefficients not systematic
chi2(24) =	(b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
=	0.60
Prob>chi2 =	1.0000
Result:	Ho cannot be rejected. Random effects model can be used safely.

prod_r	FE	RE	Difference
tax	-0.9804	-0.9840	0.0035
fpr	0.4990	0.4926	0.0064
m_prod	0.3783	0.3825	-0.0042
gpi3	0.1256	0.1252	0.0004
year2	0.1328	0.1335	-0.0007
year3	0.2229	0.2234	-0.0005
year4	0.3775	0.3777	-0.0002
year5	0.4996	0.4997	-0.0002
year6	0.5620	0.5617	0.0002
year7	0.4889	0.4861	0.0029
year8	0.3658	0.3624	0.0034
year9	0.3627	0.3584	0.0043
year10	0.3673	0.3630	0.0043
year11	0.1863	0.1825	0.0038
year12	0.1642	0.1607	0.0035
year13	0.1174	0.1136	0.0038
year14	0.1984	0.1945	0.0038
year15	0.1915	0.1873	0.0042
year16	0.0811	0.0765	0.0046
year17	0.0891	0.0851	0.0040
year18	0.2086	0.2046	0.0040
year19	0.2117	0.2073	0.0044
year20	0.2568	0.2527	0.0041

Auto-correlation: graphical approximation

Production value / GDP: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

Dataset excludes Ireland

prod_r[country2,t] = Xb + u[country2] + e[country2,t]

Test:	Var(u) =	0
	chi2(1) =	1791.12
	Prob > chi2 =	0.0000

Result: Within-unit correlation cannot be ruled out

Random effects model corrected for autocorrelation

Dependent variable: prod_r
Dataset excludes Ireland

xtregar prod_r tax fpr m_prod gpi3 year2-year20

Random-effects GLS regression			Number of obs =	260	
Group variable (i) : country2			Number of groups =	13	
R-sq:	within =	0.6263	Obs per group:	min =	20
	between =	0.1828		avg =	20
	overall =	0.2487		max =	20
			Wald chi2(24) =	688.13	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

prod_r	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.3531	0.1289	-2.7400	0.0060	-0.6058	-0.1004
fpr	0.1236	0.0751	1.6500	0.1000	-0.0236	0.2708
m_prod	0.1228	0.0810	1.5200	0.1300	-0.0360	0.2816
gpi3	0.1809	0.0507	3.5700	0.0000	0.0817	0.2802
year2	0.1954	0.0233	8.3900	0.0000	0.1498	0.2410
year3	0.2901	0.0310	9.3500	0.0000	0.2293	0.3509
year4	0.4327	0.0371	11.6800	0.0000	0.3600	0.5053
year5	0.5667	0.0428	13.2500	0.0000	0.4828	0.6505
year6	0.6294	0.0470	13.3900	0.0000	0.5373	0.7216
year7	0.4058	0.0591	6.8700	0.0000	0.2899	0.5216
year8	0.2614	0.0651	4.0100	0.0000	0.1338	0.3891
year9	0.2440	0.0720	3.3900	0.0010	0.1030	0.3850
year10	0.2774	0.0715	3.8800	0.0000	0.1373	0.4175
year11	0.1194	0.0703	1.7000	0.0890	-0.0183	0.2571
year12	0.1063	0.0699	1.5200	0.1280	-0.0307	0.2434
year13	0.0646	0.0742	0.8700	0.3840	-0.0809	0.2101
year14	0.1766	0.0763	2.3100	0.0210	0.0270	0.3261
year15	0.1774	0.0812	2.1900	0.0290	0.0183	0.3366
year16	0.0814	0.0845	0.9600	0.3350	-0.0842	0.2470
year17	0.0994	0.0836	1.1900	0.2350	-0.0645	0.2633
year18	0.2211	0.0852	2.6000	0.0090	0.0541	0.3880
year19	0.1931	0.0893	2.1600	0.0310	0.0181	0.3682
year20	0.2676	0.0895	2.9900	0.0030	0.0921	0.4430
_cons	-4.5274	0.5334	-8.4900	0.0000	-5.5729	-3.4820
rho_ar	0.88245 (estimated autocorrelation coefficient)					
sigma_u	0.34890					
sigma_e	0.06892					
rho_fov	0.96245 (fraction of variance due to u_i)					
theta	0.72683					

Heteroskedasticity: graphical approximation

Production value / GDP: Predicted values against residuals

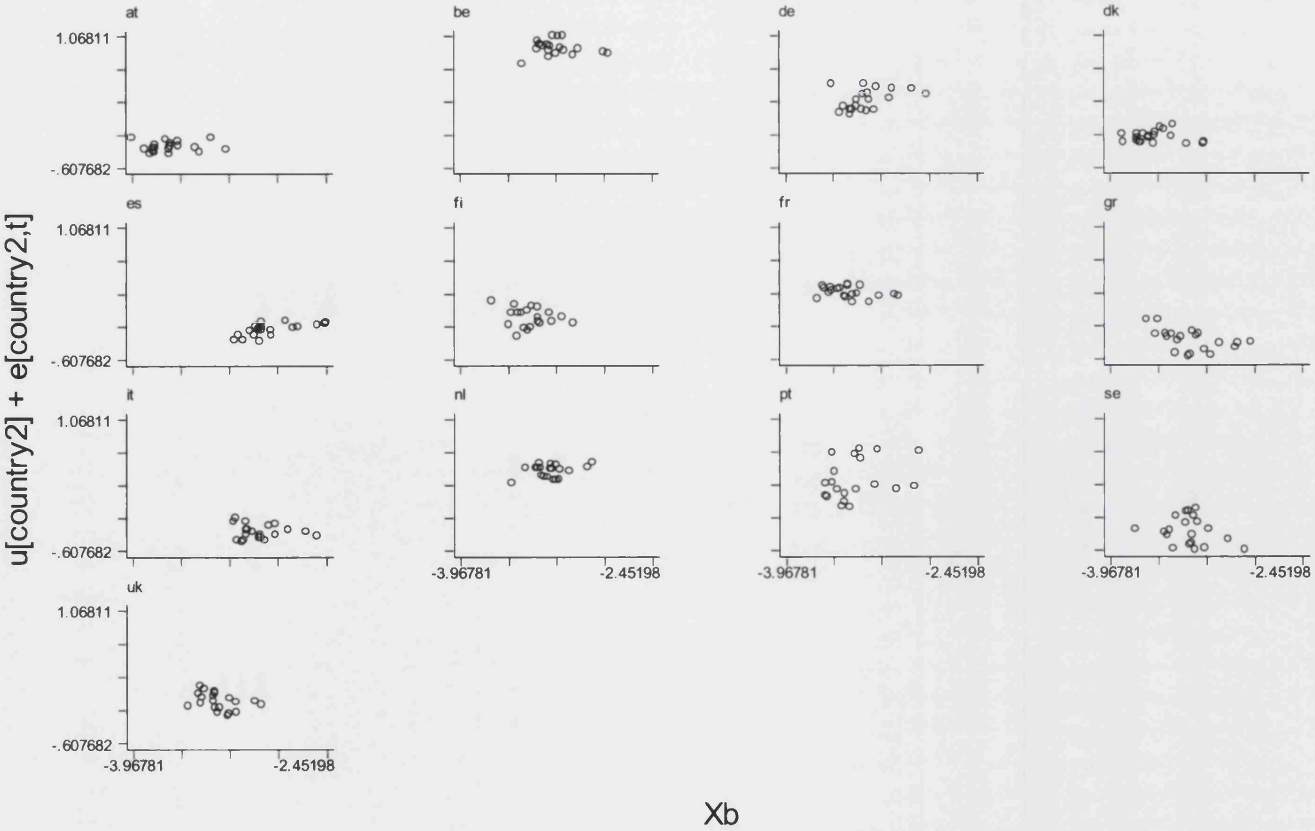


Table 44 Regression models on CI production in absolute terms, Ireland included

Fixed effects model

Dependent variable: prod_a
Dataset includes Ireland

xtreg prod_a tax fpr m_prod gdp gpi3 year2-year20, fe

Fixed-effects (within) regression			Number of obs =	280	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.7166	Obs per group:	min =	20
	between =	0.8757		avg =	20
	overall =	0.8644		max =	20
			F(24,242) =	25.49	
corr(u_i, Xb) =		0.4129	Prob > F =	0.0000	

prod_a	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Int.]
tax	-1.6644	0.1673	-9.9500	0.0000	-1.9940	-1.3348
fpr	0.5275	0.1143	4.6200	0.0000	0.3024	0.7526
m_prod	0.2300	0.1165	1.9700	0.0490	0.0005	0.4595
gdp	0.7558	0.1181	6.4000	0.0000	0.5233	0.9884
gpi3	0.2165	0.0842	2.5700	0.0110	0.0507	0.3823
year2	0.1104	0.0706	1.5600	0.1190	-0.0286	0.2494
year3	0.1935	0.0740	2.6100	0.0100	0.0476	0.3393
year4	0.3640	0.0785	4.6300	0.0000	0.2093	0.5186
year5	0.4907	0.0832	5.9000	0.0000	0.3267	0.6546
year6	0.5615	0.0834	6.7300	0.0000	0.3972	0.7258
year7	0.5942	0.0845	7.0300	0.0000	0.4278	0.7606
year8	0.5300	0.0887	5.9700	0.0000	0.3552	0.7048
year9	0.5575	0.0970	5.7500	0.0000	0.3665	0.7485
year10	0.5556	0.0947	5.8700	0.0000	0.3691	0.7420
year11	0.4211	0.0972	4.3300	0.0000	0.2296	0.6126
year12	0.4174	0.0964	4.3300	0.0000	0.2275	0.6073
year13	0.4036	0.1043	3.8700	0.0000	0.1980	0.6091
year14	0.4533	0.1012	4.4800	0.0000	0.2540	0.6527
year15	0.4818	0.1097	4.3900	0.0000	0.2658	0.6978
year16	0.4075	0.1210	3.3700	0.0010	0.1692	0.6458
year17	0.4217	0.1213	3.4800	0.0010	0.1827	0.6607
year18	0.5727	0.1200	4.7700	0.0000	0.3364	0.8091
year19	0.6152	0.1247	4.9300	0.0000	0.3695	0.8609
year20	0.6848	0.1259	5.4400	0.0000	0.4368	0.9329
_cons	-0.8167	1.9061	-0.4300	0.6690	-4.5714	2.9381
sigma_u	0.4938					
sigma_e	0.1750					
rho	0.8884 (fraction of variance due to u_i)					

F test that all u_i=0: F(13, 242) = 88.91 Prob > F = 0.0000

Random effects model

Dependent variable: prod_a
Dataset includes Ireland

xtreg prod_a tax fpr m_prod gdp gpi3 year2-year20, re

Random-effects GLS regression			Number of obs =	280	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.7151	Obs per group:	min =	20
	between =	0.8942		avg =	20
	overall =	0.8833		max =	20
Random effects u_i ~ Gaussian			Wald chi2(24) =	698.61	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

prod_a	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Int.]
tax	-1.6658	0.1594	-10.4500	0.0000	-1.9782	-1.3533
fpr	0.5192	0.1091	4.7600	0.0000	0.3053	0.7330
m_prod	0.2982	0.1068	2.7900	0.0050	0.0888	0.5076
gdp	0.8766	0.0816	10.7400	0.0000	0.7166	1.0366
gpi3	0.2217	0.0809	2.7400	0.0060	0.0631	0.3802
year2	0.1313	0.0692	1.9000	0.0580	-0.0043	0.2669
year3	0.2214	0.0713	3.1100	0.0020	0.0817	0.3611
year4	0.3982	0.0740	5.3800	0.0000	0.2532	0.5432
year5	0.5300	0.0773	6.8600	0.0000	0.3785	0.6816
year6	0.5968	0.0780	7.6500	0.0000	0.4439	0.7497
year7	0.5871	0.0824	7.1300	0.0000	0.4256	0.7485
year8	0.4975	0.0865	5.7500	0.0000	0.3280	0.6671
year9	0.5110	0.0935	5.4600	0.0000	0.3277	0.6944
year10	0.5098	0.0913	5.5800	0.0000	0.3309	0.6887
year11	0.3547	0.0905	3.9200	0.0000	0.1773	0.5321
year12	0.3511	0.0895	3.9200	0.0000	0.1757	0.5265
year13	0.3258	0.0952	3.4200	0.0010	0.1391	0.5124
year14	0.3878	0.0946	4.1000	0.0000	0.2024	0.5731
year15	0.4051	0.1011	4.0100	0.0000	0.2071	0.6032
year16	0.3110	0.1079	2.8800	0.0040	0.0996	0.5225
year17	0.3249	0.1075	3.0200	0.0030	0.1141	0.5357
year18	0.4808	0.1077	4.4700	0.0000	0.2698	0.6918
year19	0.5180	0.1120	4.6200	0.0000	0.2984	0.7375
year20	0.5870	0.1127	5.2100	0.0000	0.3661	0.8078
_cons	-2.4940	1.4449	-1.7300	0.0840	-5.3259	0.3379
sigma_u	0.464342					
sigma_e	0.175012					
rho	0.875614 (fraction of variance due to u_i)					

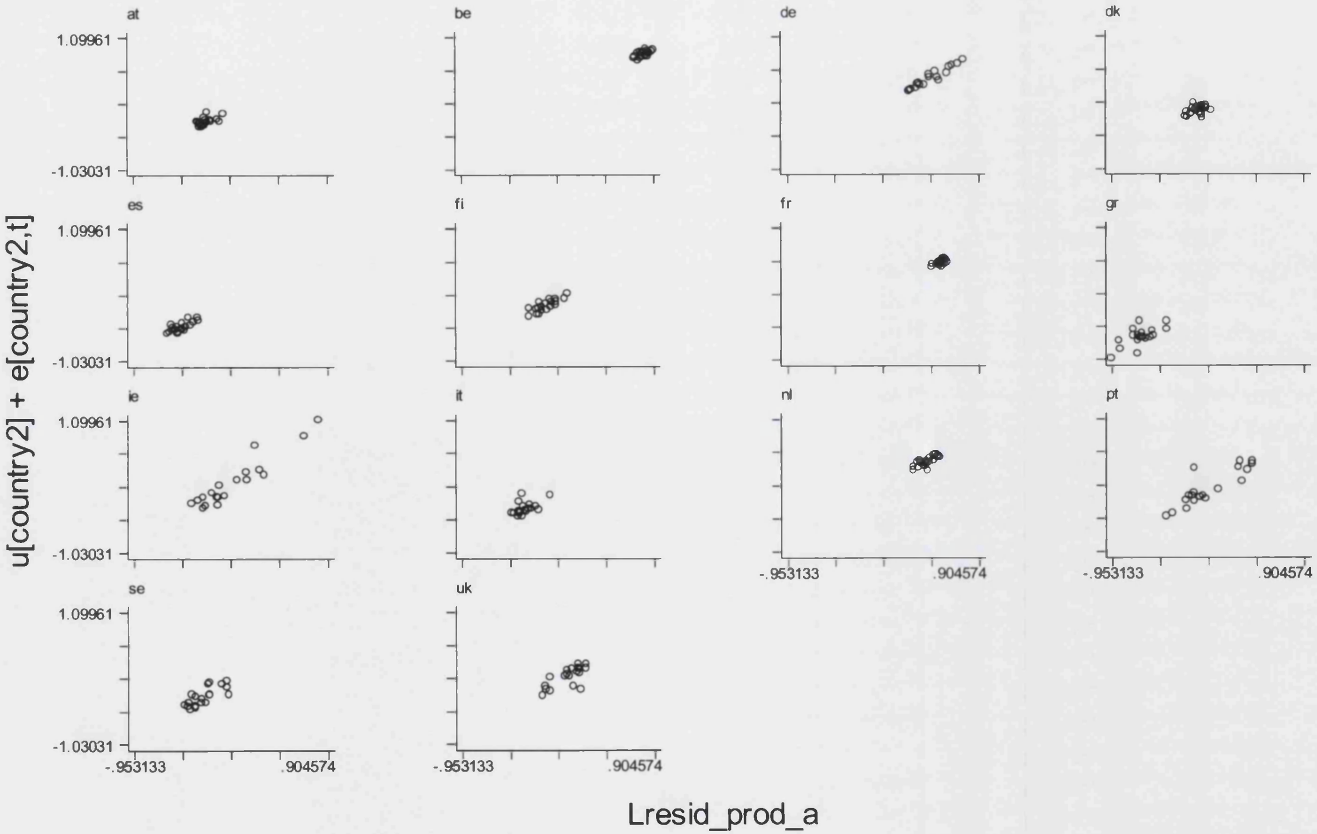
Hausman specification test

Test:	Ho: difference in coefficients not systematic
chi2(24) =	(b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
	= 3.89
Prob>chi2 =	1.0000
Result:	Ho cannot be rejected. Random effects model can be used safely.

prod_a	FE	RE	Difference
tax	-1.6644	-1.6658	0.0014
fpr	0.5275	0.5192	0.0083
m_prod	0.2300	0.2982	-0.0682
gdp	0.7558	0.8766	-0.1208
gpi3	0.2165	0.2217	-0.0051
year2	0.1104	0.1313	-0.0209
year3	0.1935	0.2214	-0.0280
year4	0.3640	0.3982	-0.0342
year5	0.4907	0.5300	-0.0393
year6	0.5615	0.5968	-0.0353
year7	0.5942	0.5871	0.0071
year8	0.5300	0.4975	0.0325
year9	0.5575	0.5110	0.0465
year10	0.5556	0.5098	0.0458
year11	0.4211	0.3547	0.0665
year12	0.4174	0.3511	0.0663
year13	0.4036	0.3258	0.0778
year14	0.4533	0.3878	0.0656
year15	0.4818	0.4051	0.0767
year16	0.4075	0.3110	0.0965
year17	0.4217	0.3249	0.0968
year18	0.5727	0.4808	0.0920
year19	0.6152	0.5180	0.0972
year20	0.6848	0.5870	0.0979

Auto-correlation: graphical approximation

Production value in absolute terms: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

Dataset includes Ireland

prod_a[country2,t] = Xb + u[country2] + e[country2,t]

Test:	Var(u) =	0
	chi2(1) =	1714.78
	Prob > chi2 =	0.0000

Result: Within-unit correlation cannot be ruled out

Random effects model corrected for autocorrelation

Dependent variable: prod_a
Dataset includes Ireland

xtregar prod_a tax fpr m_prod gdp gpl3 year2-year20

Random-effects GLS regression			Number of obs =	280	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.6465	Obs per group:	min =	20
	between =	0.8992		avg =	20
	overall =	0.8789		max =	20
			Wald chi2(25) =	267.47	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

prod_a	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.4022	0.1393	-2.8900	0.0040	-0.6752	-0.1291
fpr	0.0054	0.0784	0.0700	0.9450	-0.1483	0.1591
m_prod	0.0672	0.0909	0.7400	0.4600	-0.1110	0.2455
gdp	0.7396	0.0759	9.7500	0.0000	0.5909	0.8883
gpl3	0.1452	0.0594	2.4500	0.0140	0.0288	0.2616
year2	0.1708	0.0282	6.0600	0.0000	0.1155	0.2261
year3	0.2385	0.0392	6.0900	0.0000	0.1617	0.3153
year4	0.3695	0.0486	7.6100	0.0000	0.2743	0.4646
year5	0.4935	0.0569	8.6800	0.0000	0.3821	0.6050
year6	0.5591	0.0608	9.1900	0.0000	0.4399	0.6783
year7	0.3672	0.0662	5.5500	0.0000	0.2375	0.4969
year8	0.2693	0.0720	3.7400	0.0000	0.1282	0.4105
year9	0.2685	0.0803	3.3400	0.0010	0.1111	0.4258
year10	0.3102	0.0805	3.8600	0.0000	0.1525	0.4679
year11	0.2036	0.0819	2.4900	0.0130	0.0431	0.3641
year12	0.2130	0.0823	2.5900	0.0100	0.0517	0.3743
year13	0.1949	0.0886	2.2000	0.0280	0.0213	0.3684
year14	0.2831	0.0893	3.1700	0.0020	0.1081	0.4582
year15	0.3070	0.0957	3.2100	0.0010	0.1195	0.4945
year16	0.2505	0.1021	2.4500	0.0140	0.0503	0.4507
year17	0.2871	0.1018	2.8200	0.0050	0.0876	0.4865
year18	0.4291	0.1028	4.1700	0.0000	0.2276	0.6306
year19	0.4142	0.1076	3.8500	0.0000	0.2033	0.6251
year20	0.5173	0.1084	4.7700	0.0000	0.3048	0.7297
_cons	-0.2462	1.2263	-0.2000	0.8410	-2.6497	2.1572
rho_ar	0.93563 (estimated autocorrelation coefficient)					
sigma_u	0.34546					
sigma_e	0.07722					
rho_fov	0.95242 (fraction of variance due to u_i)					
theta	0.55585					

Heteroskedasticity: graphical approximation

Production value in absolute terms: Predicted values against residuals

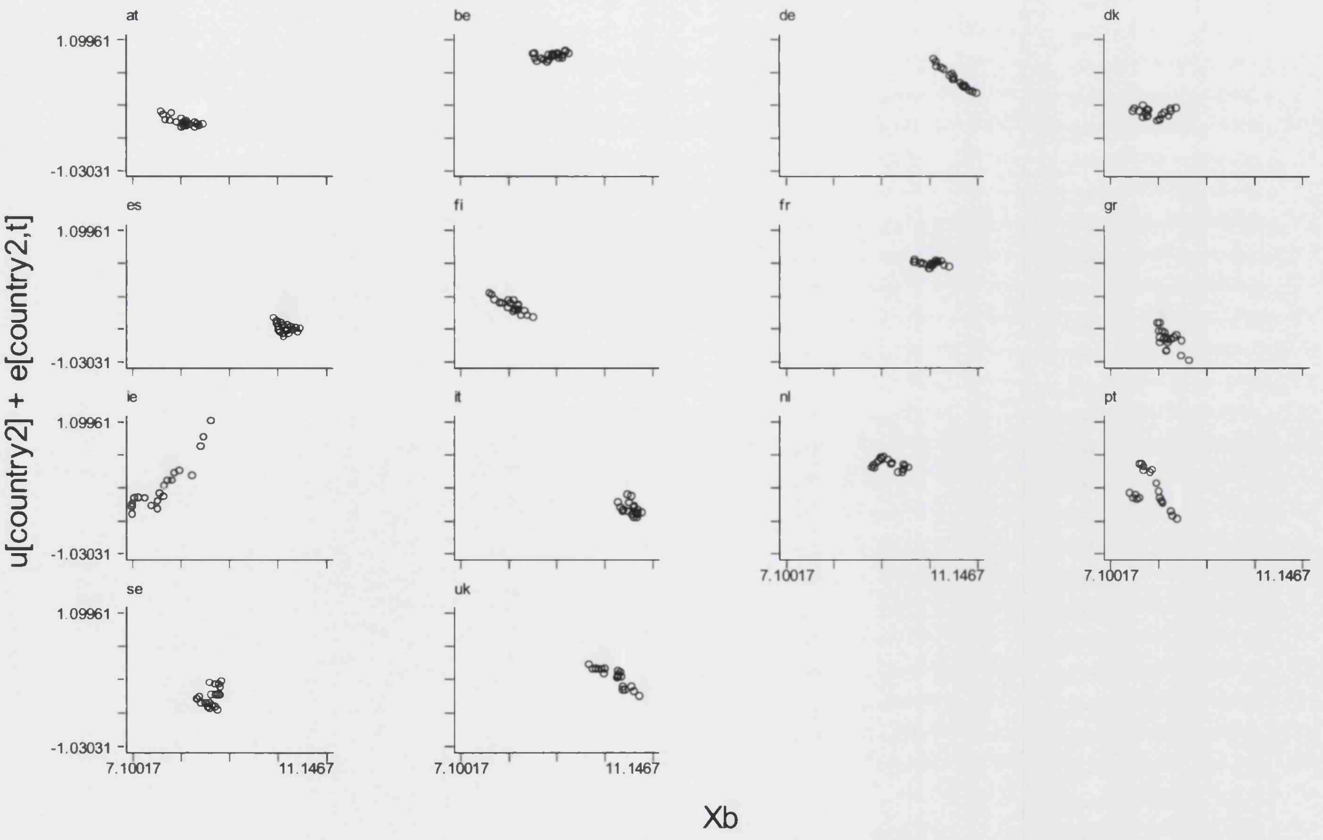


Table 45 Regression models on CI production in absolute terms, Ireland excluded

Fixed effects model

Dependent variable: prod_a
Dataset excludes Ireland

xtreg prod_a tax fpr m_prod gdp gpi3 year2-year20, fe

Fixed-effects (within) regression			Number of obs =	260	
Group variable (i) : *country2*			Number of groups =	13	
R-sq:	within =	0.8538	Obs per group:	min =	20
	between =	0.7363		avg =	20
	overall =	0.2149		max =	20
			F(24,223) =	54.25	
corr(u_i, Xb) =		-0.6049	Prob > F =	0.0000	

prod_a	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Int.]
tax	-0.2955	0.0961	-3.0800	0.0020	-0.4849	-0.1062
fpr	0.1622	0.0578	2.8100	0.0050	0.0484	0.2761
m_prod	-0.0113	0.0568	-0.2000	0.8430	-0.1231	0.1006
gdp	-0.1841	0.0656	-2.8100	0.0050	-0.3134	-0.0548
gpi3	-0.1324	0.0430	-3.0800	0.0020	-0.2172	-0.0477
year2	-0.0435	0.0352	-1.2300	0.2190	-0.1129	0.0260
year3	-0.0546	0.0376	-1.4500	0.1470	-0.1287	0.0194
year4	-0.0040	0.0406	-0.1000	0.9210	-0.0841	0.0760
year5	0.0507	0.0435	1.1700	0.2450	-0.0351	0.1365
year6	0.1271	0.0437	2.9100	0.0040	0.0411	0.2132
year7	0.2677	0.0433	6.1800	0.0000	0.1824	0.3531
year8	0.3455	0.0442	7.8200	0.0000	0.2584	0.4326
year9	0.4320	0.0476	9.0700	0.0000	0.3382	0.5258
year10	0.4522	0.0464	9.7500	0.0000	0.3608	0.5436
year11	0.4848	0.0475	10.2100	0.0000	0.3912	0.5784
year12	0.4824	0.0472	10.2100	0.0000	0.3893	0.5755
year13	0.5189	0.0510	10.1700	0.0000	0.4184	0.6195
year14	0.4838	0.0493	9.8100	0.0000	0.3866	0.5809
year15	0.5560	0.0534	10.4200	0.0000	0.4508	0.6611
year16	0.6217	0.0591	10.5100	0.0000	0.5052	0.7382
year17	0.6521	0.0594	10.9700	0.0000	0.5350	0.7693
year18	0.7018	0.0582	12.0600	0.0000	0.5871	0.8165
year19	0.7021	0.0602	11.6600	0.0000	0.5834	0.8208
year20	0.7664	0.0608	12.6100	0.0000	0.6466	0.8862
_cons	11.7761	1.0276	11.4600	0.0000	9.7510	13.8012
sigma_u	1.4155					
sigma_e	0.0834					
rho	0.9965 (fraction of variance due to u_i)					

F test that all u_i=0: F(12, 242) = 429.18 Prob > F = 0.0000

Random effects model

Dependent variable: prod_a
Dataset excludes Ireland

xtreg prod_a tax fpr m_prod gdp gpi3 year2-year20, re

Random-effects GLS regression			Number of obs =	260	
Group variable (i) : *country2*			Number of groups =	13	
R-sq:	within =	0.842	Obs per group:	min =	20
	between =	0.7825		avg =	20
	overall =	0.4634		max =	20
Random effects u_i ~ Gaussian			Wald chi2(24) =	990.85	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

prod_a	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Int.]
tax	-0.4841	0.1065	-4.5400	0.0000	-0.6929	-0.2753
fpr	0.2449	0.0648	3.7800	0.0000	0.1179	0.3719
m_prod	0.1061	0.0630	1.6800	0.0920	-0.0174	0.2295
gdp	0.0918	0.0661	1.3900	0.1650	-0.0377	0.2214
gpi3	-0.0694	0.0483	-1.4400	0.1510	-0.1641	0.0254
year2	-0.0043	0.0401	-0.1100	0.9140	-0.0829	0.0742
year3	0.0069	0.0423	0.1600	0.8710	-0.0761	0.0898
year4	0.0811	0.0452	1.7900	0.0730	-0.0075	0.1697
year5	0.1506	0.0482	3.1300	0.0020	0.0562	0.2450
year6	0.2226	0.0485	4.5900	0.0000	0.1276	0.3176
year7	0.3143	0.0490	6.4100	0.0000	0.2181	0.4104
year8	0.3448	0.0504	6.8400	0.0000	0.2460	0.4436
year9	0.4090	0.0542	7.5500	0.0000	0.3028	0.5151
year10	0.4245	0.0527	8.0500	0.0000	0.3211	0.5279
year11	0.4074	0.0532	7.6500	0.0000	0.3030	0.5118
year12	0.4005	0.0529	7.5800	0.0000	0.2969	0.5041
year13	0.4161	0.0567	7.3400	0.0000	0.3050	0.5272
year14	0.4061	0.0554	7.3400	0.0000	0.2976	0.5146
year15	0.4582	0.0596	7.6900	0.0000	0.3415	0.5749
year16	0.4813	0.0650	7.4000	0.0000	0.3539	0.6088
year17	0.5069	0.0652	7.7700	0.0000	0.3790	0.6347
year18	0.5725	0.0643	8.9000	0.0000	0.4465	0.6985
year19	0.5737	0.0667	8.6100	0.0000	0.4430	0.7044
year20	0.6327	0.0672	9.4200	0.0000	0.5010	0.7643
_cons	7.7243	1.0627	7.2700	0.0000	5.6415	9.8072
sigma_u	0.468225					
sigma_e	0.083446					
rho	0.969216 (fraction of variance due to u_i)					

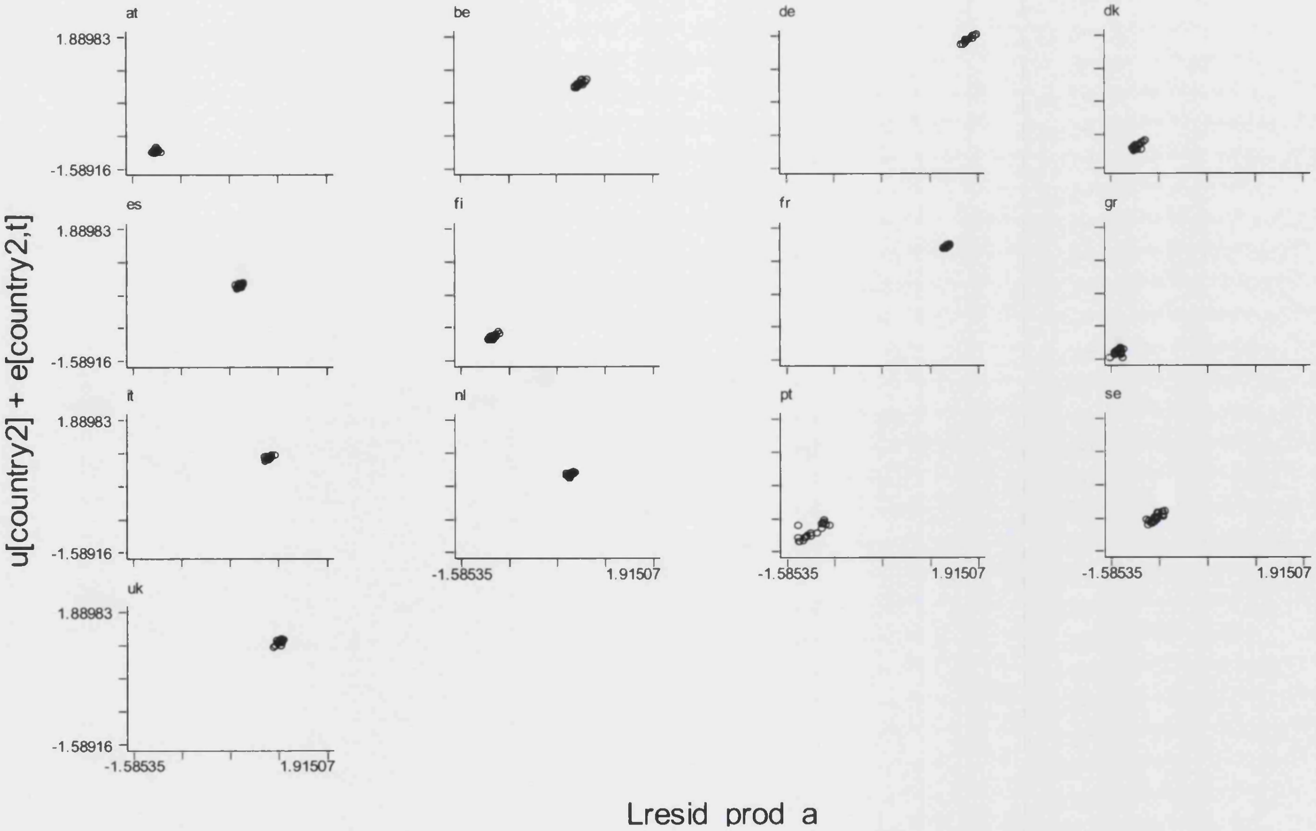
Hausman specification test

Test:	Ho: difference in coefficients not systematic
chi2(24) =	(b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
=	0.00
Prob>chi2 =	1.0000
Result:	Ho cannot be rejected. Random effects model can be used safely.

prod_a	FE	RE	Difference
tax	-0.2955	-0.4841	0.1885
fpr	0.1622	0.2449	-0.0827
m_prod	-0.0113	0.1061	-0.1174
gdp	-0.1841	0.0918	-0.2759
gpi3	-0.1324	-0.0694	-0.0631
year2	-0.0435	-0.0043	-0.0391
year3	-0.0546	0.0069	-0.0615
year4	-0.0040	0.0811	-0.0851
year5	0.0507	0.1506	-0.0999
year6	0.1271	0.2226	-0.0955
year7	0.2677	0.3143	-0.0465
year8	0.3455	0.3448	0.0007
year9	0.4320	0.4090	0.0230
year10	0.4522	0.4245	0.0277
year11	0.4848	0.4074	0.0774
year12	0.4824	0.4005	0.0819
year13	0.5189	0.4161	0.1028
year14	0.4838	0.4061	0.0776
year15	0.5560	0.4582	0.0978
year16	0.6217	0.4813	0.1404
year17	0.6521	0.5069	0.1453
year18	0.7018	0.5725	0.1293
year19	0.7021	0.5737	0.1284
year20	0.7664	0.6327	0.1338

Auto-correlation: graphical approximation

Production value in absolute terms: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

Dataset excludes Ireland

prod_a[country2,t] = Xb + u[country2] + e[country2,t]

Test:	Var(u) =	0
	chi2(1) =	1792.88
	Prob > chi2 =	0.0000

Result: Within-unit correlation cannot be ruled out

Random effects model corrected for autocorrelation

Dependent variable: prod_a
Dataset excludes Ireland

xtregar prod_a tax fpr m_prod gdp gpi3 year2-year20

Random-effects GLS regression			Number of obs =	260	
Group variable (i) : country2			Number of groups =	13	
R-sq:	within =	0.7527	Obs per group:	min =	20
	between =	0.9025		avg =	20
	overall =	0.878		max =	20
			Wald chi2(25) =	311.99	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

prod_a	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.3629	0.1190	-3.0500	0.0020	-0.5960	-0.1297
fpr	0.1108	0.0707	1.5700	0.1170	-0.0278	0.2494
m_prod	0.1361	0.0731	1.8600	0.0630	-0.0072	0.2795
gdp	0.5557	0.0668	8.3100	0.0000	0.4247	0.6866
gpi3	0.0583	0.0501	1.1600	0.2440	-0.0398	0.1565
year2	0.1060	0.0256	4.1400	0.0000	0.0558	0.1562
year3	0.1575	0.0348	4.5200	0.0000	0.0892	0.2257
year4	0.2621	0.0423	6.2000	0.0000	0.1792	0.3450
year5	0.3643	0.0488	7.4600	0.0000	0.2685	0.4600
year6	0.4282	0.0513	8.3400	0.0000	0.3276	0.5289
year7	0.3276	0.0543	6.0300	0.0000	0.2211	0.4341
year8	0.2628	0.0582	4.5200	0.0000	0.1488	0.3768
year9	0.2775	0.0643	4.3200	0.0000	0.1515	0.4035
year10	0.3053	0.0633	4.8200	0.0000	0.1812	0.4293
year11	0.2205	0.0634	3.4800	0.0010	0.0962	0.3449
year12	0.2132	0.0630	3.3900	0.0010	0.0899	0.3366
year13	0.1966	0.0676	2.9100	0.0040	0.0641	0.3291
year14	0.2509	0.0671	3.7400	0.0000	0.1194	0.3823
year15	0.2737	0.0720	3.8000	0.0000	0.1326	0.4148
year16	0.2342	0.0771	3.0400	0.0020	0.0831	0.3853
year17	0.2599	0.0765	3.4000	0.0010	0.1100	0.4099
year18	0.3538	0.0764	4.6300	0.0000	0.2040	0.5036
year19	0.3339	0.0803	4.1600	0.0000	0.1766	0.4912
year20	0.4049	0.0802	5.0500	0.0000	0.2476	0.5621
_cons	1.6437	1.0516	1.5600	0.1180	-0.4174	3.7048
rho_ar	0.81326 (estimated autocorrelation coefficient)					
sigma_u	0.34824					
sigma_e	0.07214					
rho_fov	0.95885 (fraction of variance due to u_i)					
theta	0.79727					

Heteroskedasticity: graphical approximation

Production value in absolute terms: Predicted values against residuals

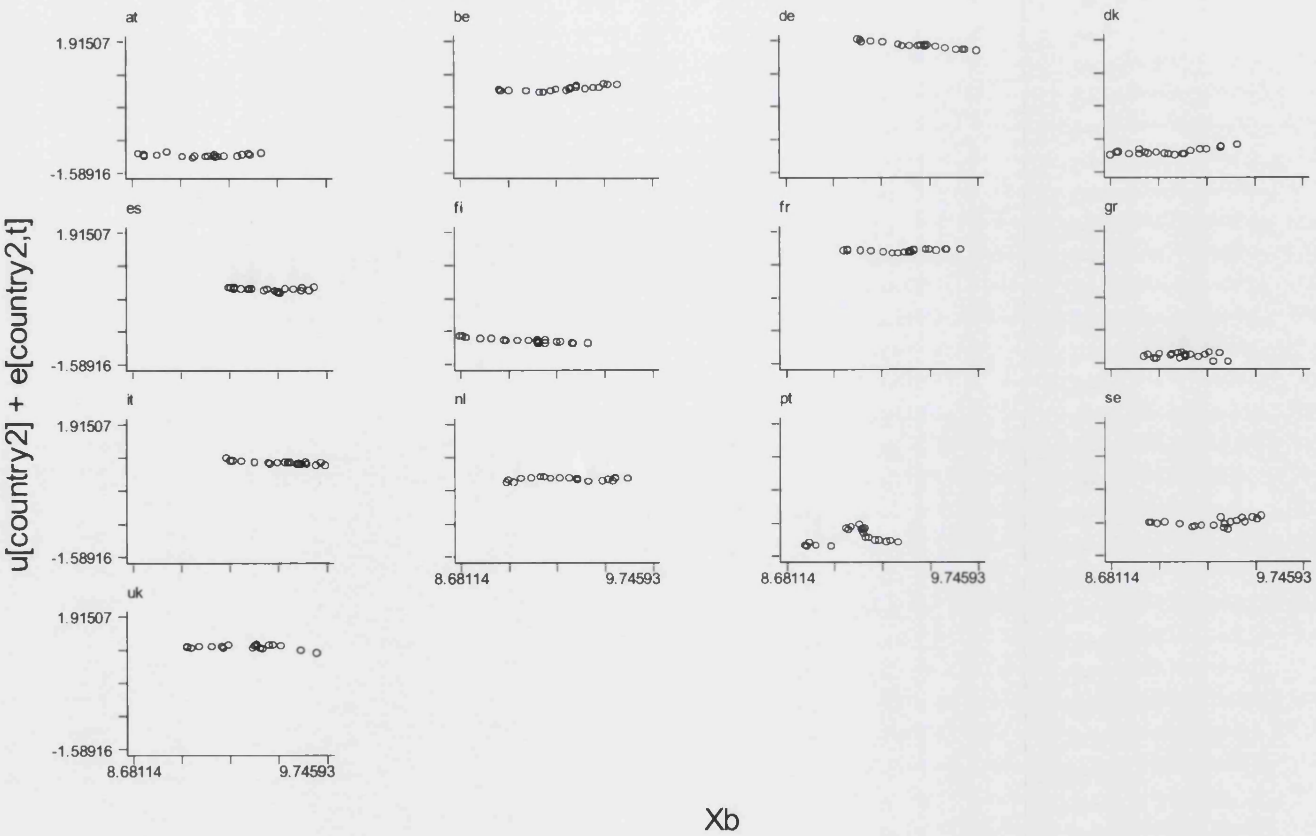


Table 46 Regression models on CI employees / total workforce, Ireland included

Fixed effects model

Dependent variable: empl_r
Dataset includes Ireland

xtreg empl_r tax fpr m_prod gdp gpi3 year2-year20, fe

Fixed-effects (within) regression			Number of obs =	280	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.2178	Obs per group:	min =	20
	between =	0.0003		avg =	20
	overall =	0.0085		max =	20
			F(23,243) =		2.94
corr(u_i, Xb) =		-0.202	Prob > F =		0.0000

empl_r	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Int.]
tax	-0.6088	0.1408	-4.3200	0.0000	-0.8861	-0.3315
fpr	0.0686	0.0953	0.7200	0.4720	-0.1191	0.2563
m_prod	0.0584	0.0935	0.6200	0.5330	-0.1257	0.2424
gpi3	0.0013	0.0702	0.0200	0.9850	-0.1369	0.1395
year2	-0.0173	0.0585	-0.3000	0.7670	-0.1326	0.0979
year3	-0.0226	0.0591	-0.3800	0.7030	-0.1390	0.0939
year4	-0.0162	0.0598	-0.2700	0.7870	-0.1340	0.1016
year5	-0.0101	0.0616	-0.1600	0.8690	-0.1314	0.1111
year6	-0.0112	0.0627	-0.1800	0.8580	-0.1347	0.1122
year7	0.0198	0.0713	0.2800	0.7820	-0.1207	0.1602
year8	0.0220	0.0758	0.2900	0.7710	-0.1272	0.1713
year9	0.0368	0.0819	0.4500	0.6530	-0.1245	0.1982
year10	0.0101	0.0798	0.1300	0.9000	-0.1472	0.1673
year11	-0.0135	0.0767	-0.1800	0.8610	-0.1644	0.1375
year12	-0.0277	0.0753	-0.3700	0.7130	-0.1761	0.1206
year13	-0.0382	0.0791	-0.4800	0.6300	-0.1940	0.1177
year14	-0.0727	0.0807	-0.9000	0.3690	-0.2317	0.0864
year15	-0.0889	0.0855	-1.0400	0.2990	-0.2574	0.0795
year16	-0.1027	0.0884	-1.1600	0.2460	-0.2768	0.0714
year17	-0.1089	0.0869	-1.2500	0.2110	-0.2802	0.0623
year18	-0.1184	0.0885	-1.3400	0.1820	-0.2928	0.0560
year19	-0.1290	0.0925	-1.3900	0.1640	-0.3112	0.0532
year20	-0.1475	0.0926	-1.5900	0.1130	-0.3300	0.0349
_cons	1.2490	0.6816	1.8300	0.0680	-0.0936	2.5917
sigma_u	0.424877					
sigma_e	0.149931					
rho	0.889265 (fraction of variance due to u_i)					

F test that all u_i=0: F(13, 243) = 74.65 Prob > F = 0.0000

Random effects model

Dependent variable: empl_r
Dataset includes Ireland

xtreg empl_r tax fpr m_prod gdp gpi3 year2-year20, re

Random-effects GLS regression			Number of obs =	280	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.2128	Obs per group:	min =	20
	between =	0.1189		avg =	20
	overall =	0.1267		max =	20
Random effects u_i ~ Gaussian			Wald chi2(23) =		66.6
corr(u_i, X) = 0 (assumed)			Prob > chi2 =		0.0000

empl_r	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Int.]
tax	-0.5258	0.1362	-3.8600	0.0000	-0.7927	-0.2589
fpr	-0.0084	0.0922	-0.0900	0.9270	-0.1892	0.1723
m_prod	0.1021	0.0892	1.1400	0.2520	-0.0727	0.2769
gpi3	-0.0284	0.0681	-0.4200	0.6770	-0.1619	0.1051
year2	-0.0106	0.0591	-0.1800	0.8580	-0.1264	0.1052
year3	-0.0202	0.0596	-0.3400	0.7340	-0.1371	0.0967
year4	-0.0202	0.0603	-0.3300	0.7380	-0.1384	0.0980
year5	-0.0162	0.0619	-0.2600	0.7940	-0.1375	0.1052
year6	-0.0212	0.0629	-0.3400	0.7360	-0.1444	0.1021
year7	-0.0250	0.0704	-0.3500	0.7230	-0.1630	0.1131
year8	-0.0299	0.0745	-0.4000	0.6880	-0.1759	0.1161
year9	-0.0247	0.0801	-0.3100	0.7580	-0.1817	0.1323
year10	-0.0481	0.0782	-0.6200	0.5380	-0.2013	0.1051
year11	-0.0687	0.0751	-0.9100	0.3600	-0.2160	0.0785
year12	-0.0794	0.0739	-1.0700	0.2830	-0.2243	0.0656
year13	-0.0941	0.0774	-1.2200	0.2240	-0.2459	0.0576
year14	-0.1270	0.0789	-1.6100	0.1080	-0.2817	0.0277
year15	-0.1477	0.0833	-1.7700	0.0760	-0.3111	0.0156
year16	-0.1643	0.0860	-1.9100	0.0560	-0.3328	0.0042
year17	-0.1641	0.0847	-1.9400	0.0530	-0.3302	0.0020
year18	-0.1753	0.0862	-2.0300	0.0420	-0.3442	-0.0063
year19	-0.1940	0.0898	-2.1600	0.0310	-0.3700	-0.0179
year20	-0.2090	0.0900	-2.3200	0.0200	-0.3854	-0.0326
_cons	1.4482	0.6728	2.1500	0.0310	0.1296	2.7668
sigma_u	0.33405					
sigma_e	0.149931					
rho	0.832331 (fraction of variance due to u_i)					

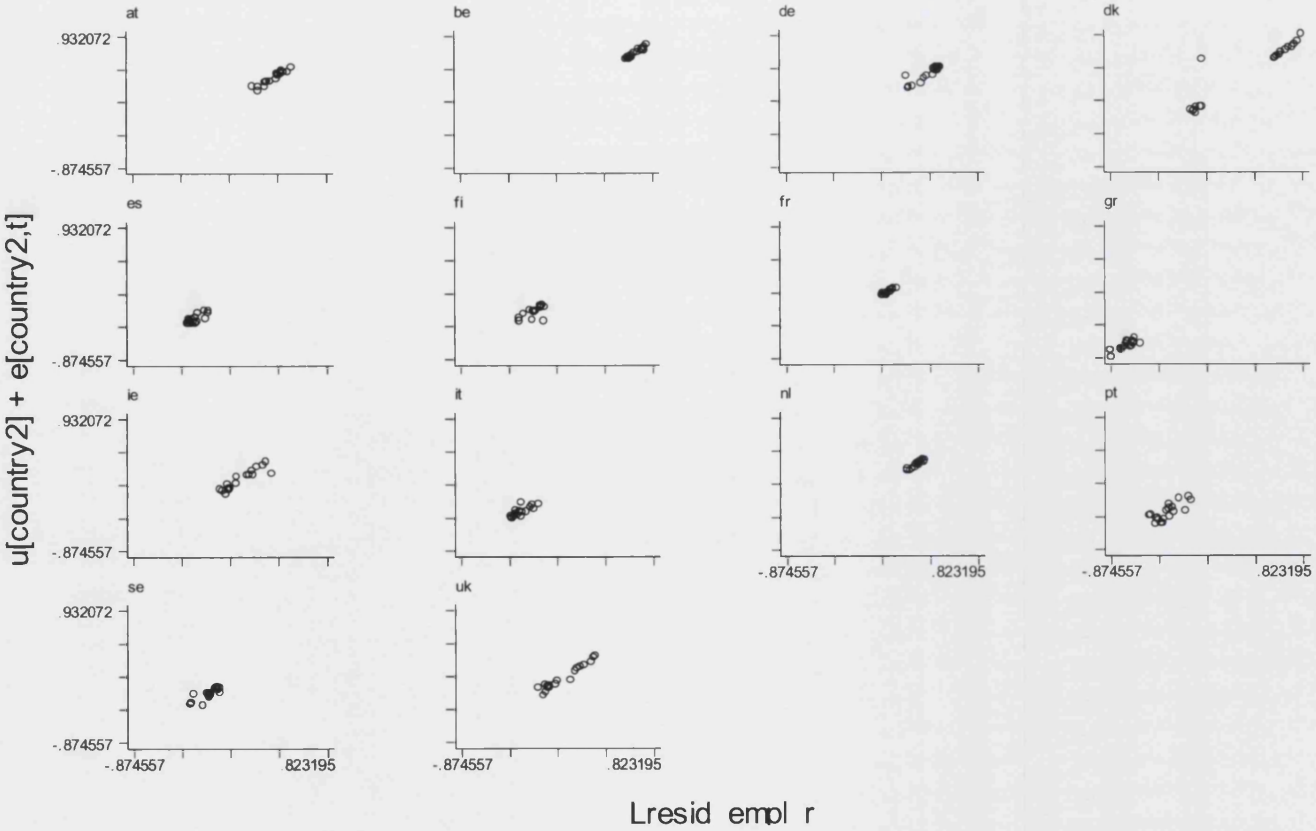
Hausman specification test

Test:	Ho: difference in coefficients not systematic
chi2(24) =	(b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
=	10.58
Prob>chi2 =	0.9871
Result:	Ho cannot be rejected.
	Random effects model can be used safely.

empl_r	FE	RE	Difference
tax	-0.6088	-0.5258	-0.0830
fpr	0.0686	-0.0084	0.0771
m_prod	0.0584	0.1021	-0.0437
gpi3	0.0013	-0.0284	0.0297
year2	-0.0173	-0.0106	-0.0067
year3	-0.0226	-0.0202	-0.0023
year4	-0.0162	-0.0202	0.0040
year5	-0.0101	-0.0162	0.0060
year6	-0.0112	-0.0212	0.0099
year7	0.0198	-0.0250	0.0447
year8	0.0220	-0.0299	0.0519
year9	0.0368	-0.0247	0.0615
year10	0.0101	-0.0481	0.0582
year11	-0.0135	-0.0687	0.0553
year12	-0.0277	-0.0794	0.0516
year13	-0.0382	-0.0941	0.0560
year14	-0.0727	-0.1270	0.0543
year15	-0.0889	-0.1477	0.0588
year16	-0.1027	-0.1643	0.0616
year17	-0.1089	-0.1641	0.0552
year18	-0.1184	-0.1753	0.0569
year19	-0.1290	-0.1940	0.0650
year20	-0.1475	-0.2090	0.0614

Auto-correlation: graphical approximation

Chemical industry employees / total workforce: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

Dataset includes Ireland

empl_r[country2,t] = Xb + u[country2] + e[country2,t]

Test:	Var(u) =	0
	chi2(1) =	1439.24
	Prob > chi2 =	0.0000

Result: Within-unit correlation cannot be ruled out

Random effects model corrected for autocorrelation

Dependent variable: empl_r
Dataset includes Ireland

xtregar empl_r tax fpr m_prod gpi3 year2-year20

Random-effects GLS regression			Number of obs =	280		
Group variable (i) : country2			Number of groups =	14		
R-sq:	within =	0.1582	Obs per group:	min =	20	
	between =	0.4245		avg =	20	
	overall =	0.2535		max =	20	
			Wald chi2(24) =		24.04	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =		0.4596	

empl_r	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.0656	0.1075	-0.6100	0.5420	-0.2763	0.1451
fpr	-0.0189	0.0605	-0.3100	0.7540	-0.1374	0.0996
m_prod	0.1151	0.0701	1.6400	0.1010	-0.0223	0.2525
gpi3	-0.0065	0.0430	-0.1500	0.8800	-0.0907	0.0777
year2	-0.0176	0.0190	-0.9300	0.3520	-0.0548	0.0195
year3	-0.0353	0.0256	-1.3800	0.1690	-0.0855	0.0150
year4	-0.0492	0.0311	-1.5800	0.1140	-0.1101	0.0118
year5	-0.0531	0.0362	-1.4700	0.1420	-0.1240	0.0178
year6	-0.0581	0.0400	-1.4500	0.1460	-0.1366	0.0203
year7	-0.0819	0.0501	-1.6400	0.1020	-0.1801	0.0163
year8	-0.0939	0.0554	-1.7000	0.0900	-0.2024	0.0146
year9	-0.0835	0.0615	-1.3600	0.1740	-0.2039	0.0370
year10	-0.0965	0.0616	-1.5700	0.1170	-0.2171	0.0241
year11	-0.1161	0.0610	-1.9000	0.0570	-0.2357	0.0034
year12	-0.1306	0.0610	-2.1400	0.0320	-0.2501	-0.0111
year13	-0.1486	0.0649	-2.2900	0.0220	-0.2759	-0.0213
year14	-0.1784	0.0671	-2.6600	0.0080	-0.3100	-0.0468
year15	-0.2041	0.0714	-2.8600	0.0040	-0.3441	-0.0640
year16	-0.2147	0.0745	-2.8800	0.0040	-0.3607	-0.0687
year17	-0.2244	0.0736	-3.0500	0.0020	-0.3687	-0.0802
year18	-0.2397	0.0753	-3.1800	0.0010	-0.3873	-0.0921
year19	-0.2694	0.0788	-3.4200	0.0010	-0.4239	-0.1149
year20	-0.2860	0.0793	-3.6000	0.0000	-0.4415	-0.1305
_cons	0.1883	0.4491	0.4200	0.6750	-0.6918	1.0684
rho_ar	0.92779 (estimated autocorrelation coefficient)					
sigma_u	0.28097					
sigma_e	0.05970					
rho_fov	0.95680 (fraction of variance due to u_i)					
theta	0.60087					

Heteroskedasticity: graphical approximation

Chemical industry employees / total workforce: Predicted values against residuals

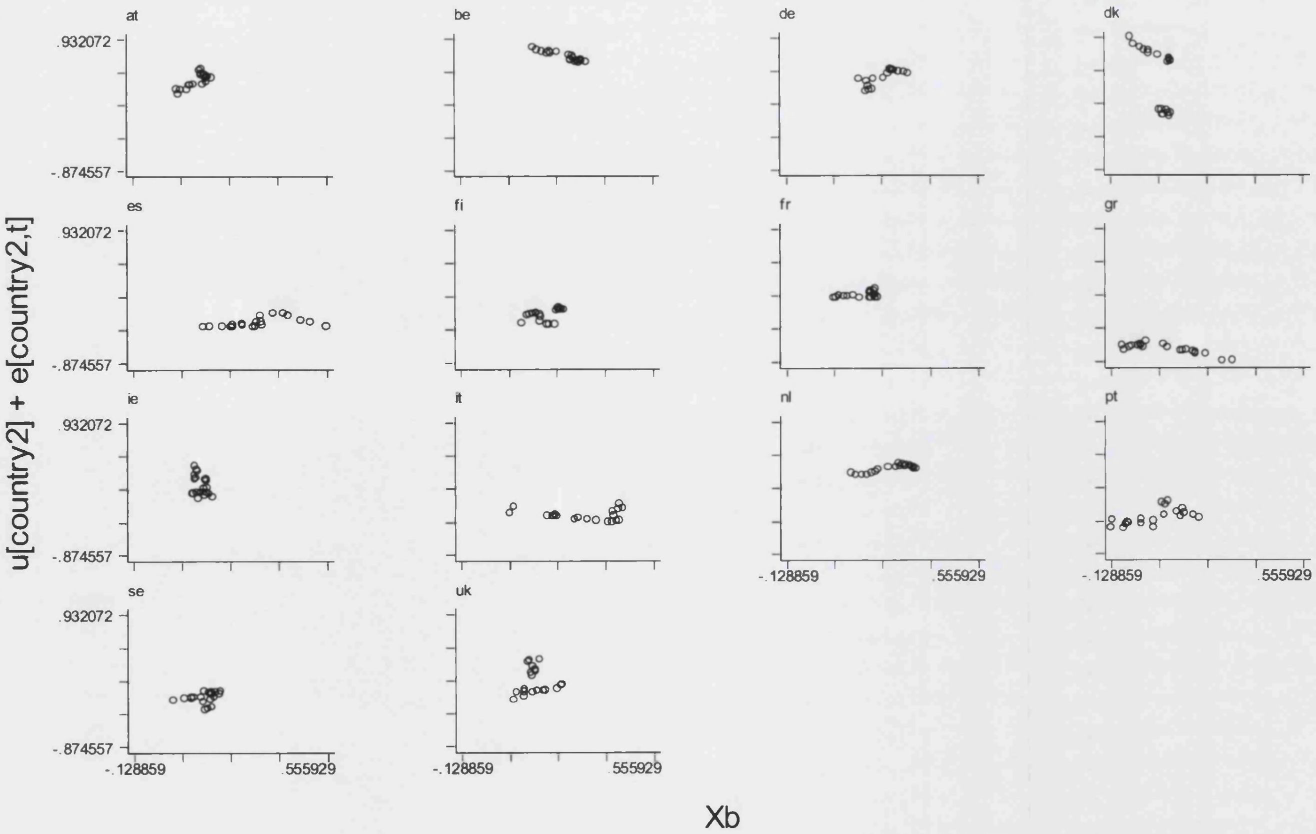


Table 47 Regression models on CI employment / total workforce, Ireland excluded

Fixed effects model

Dependent variable: empl_r
Dataset excludes Ireland

xtreg empl_r tax fpr m_prod gdp gpi3 year2-year20, fe

Fixed-effects (within) regression		Number of obs =	260	
Group variable (i) : country2		Number of groups =	13	
R-sq:	within = 0.241	Obs per group:	min =	20
	between = 0.1723		avg =	20
	overall = 0.1459		max =	20
		F(23,224) =		3.09
corr(u_i, Xb) =	0.1732	Prob > F =		0.0000

empl_r	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Int.]
tax	-0.3443	0.1588	-2.1700	0.0310	-0.6572	-0.0315
fpr	0.0247	0.0983	0.2500	0.8020	-0.1691	0.2185
m_prod	0.0779	0.0944	0.8200	0.4100	-0.1082	0.2640
gpi3	-0.0513	0.0729	-0.7000	0.4820	-0.1951	0.0924
year2	-0.0187	0.0609	-0.3100	0.7590	-0.1387	0.1013
year3	-0.0258	0.0616	-0.4200	0.6760	-0.1473	0.0957
year4	-0.0333	0.0624	-0.5300	0.5940	-0.1562	0.0896
year5	-0.0327	0.0642	-0.5100	0.6110	-0.1593	0.0939
year6	-0.0366	0.0655	-0.5600	0.5770	-0.1656	0.0925
year7	-0.0326	0.0747	-0.4400	0.6630	-0.1798	0.1146
year8	-0.0367	0.0795	-0.4600	0.6450	-0.1933	0.1200
year9	-0.0230	0.0854	-0.2700	0.7880	-0.1912	0.1452
year10	-0.0488	0.0830	-0.5900	0.5570	-0.2123	0.1148
year11	-0.0749	0.0801	-0.9400	0.3510	-0.2327	0.0829
year12	-0.0955	0.0788	-1.2100	0.2270	-0.2509	0.0598
year13	-0.1102	0.0826	-1.3300	0.1830	-0.2730	0.0525
year14	-0.1431	0.0840	-1.7000	0.0900	-0.3086	0.0224
year15	-0.1657	0.0888	-1.8700	0.0630	-0.3407	0.0094
year16	-0.1824	0.0917	-1.9900	0.0480	-0.3632	-0.0017
year17	-0.1905	0.0910	-2.0900	0.0370	-0.3699	-0.0112
year18	-0.2068	0.0924	-2.2400	0.0260	-0.3889	-0.0247
year19	-0.2150	0.0967	-2.2200	0.0270	-0.4054	-0.0245
year20	-0.2311	0.0968	-2.3900	0.0180	-0.4219	-0.0403
_cons	1.0029	0.6903	1.4500	0.1480	-0.3574	2.3632
sigma_u	0.404797					
sigma_e	0.150088					
rho	0.879142 (fraction of variance due to u_i)					

F test that all u_i=0: F(12,224) = 75.93 Prob > F = 0.0000

Random effects model

Dependent variable: empl_r
Dataset excludes Ireland

xtreg empl_r tax fpr m_prod gdp gpi3 year2-year20, re

Random-effects GLS regression		Number of obs =	260	
Group variable (i) : country2		Number of groups =	13	
R-sq:	within = 0.2372	Obs per group:	min =	20
	between = 0.4467		avg =	20
	overall = 0.3322		max =	20
Random effects u_i ~ Gaussian		Wald chi2(23) =		73.28
corr(u_i, X) = 0 (assumed)		Prob > chi2 =		0.0000

empl_r	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Int.]
tax	-0.2624	0.1509	-1.7400	0.0820	-0.5581	0.0332
fpr	-0.0459	0.0946	-0.4800	0.6280	-0.2313	0.1395
m_prod	0.1167	0.0911	1.2800	0.2000	-0.0618	0.2952
gpi3	-0.0808	0.0708	-1.1400	0.2540	-0.2197	0.0580
year2	-0.0122	0.0614	-0.2000	0.8420	-0.1325	0.1081
year3	-0.0230	0.0621	-0.3700	0.7110	-0.1447	0.0987
year4	-0.0364	0.0628	-0.5800	0.5620	-0.1595	0.0867
year5	-0.0378	0.0646	-0.5900	0.5580	-0.1645	0.0888
year6	-0.0458	0.0657	-0.7000	0.4860	-0.1746	0.0830
year7	-0.0745	0.0734	-1.0200	0.3100	-0.2183	0.0693
year8	-0.0857	0.0776	-1.1000	0.2690	-0.2379	0.0664
year9	-0.0804	0.0829	-0.9700	0.3320	-0.2428	0.0821
year10	-0.1030	0.0808	-1.2700	0.2020	-0.2613	0.0553
year11	-0.1266	0.0780	-1.6200	0.1050	-0.2795	0.0263
year12	-0.1442	0.0770	-1.8700	0.0610	-0.2950	0.0067
year13	-0.1626	0.0804	-2.0200	0.0430	-0.3202	-0.0050
year14	-0.1937	0.0819	-2.3700	0.0180	-0.3543	-0.0332
year15	-0.2204	0.0864	-2.5500	0.0110	-0.3897	-0.0510
year16	-0.2397	0.0891	-2.6900	0.0070	-0.4143	-0.0652
year17	-0.2435	0.0886	-2.7500	0.0060	-0.4173	-0.0698
year18	-0.2608	0.0900	-2.9000	0.0040	-0.4371	-0.0845
year19	-0.2763	0.0937	-2.9500	0.0030	-0.4599	-0.0927
year20	-0.2889	0.0941	-3.0700	0.0020	-0.4733	-0.1045
_cons	1.1856	0.6918	1.7100	0.0870	-0.1703	2.5414
sigma_u	0.329659					
sigma_e	0.150088					
rho	0.828307 (fraction of variance due to u_i)					

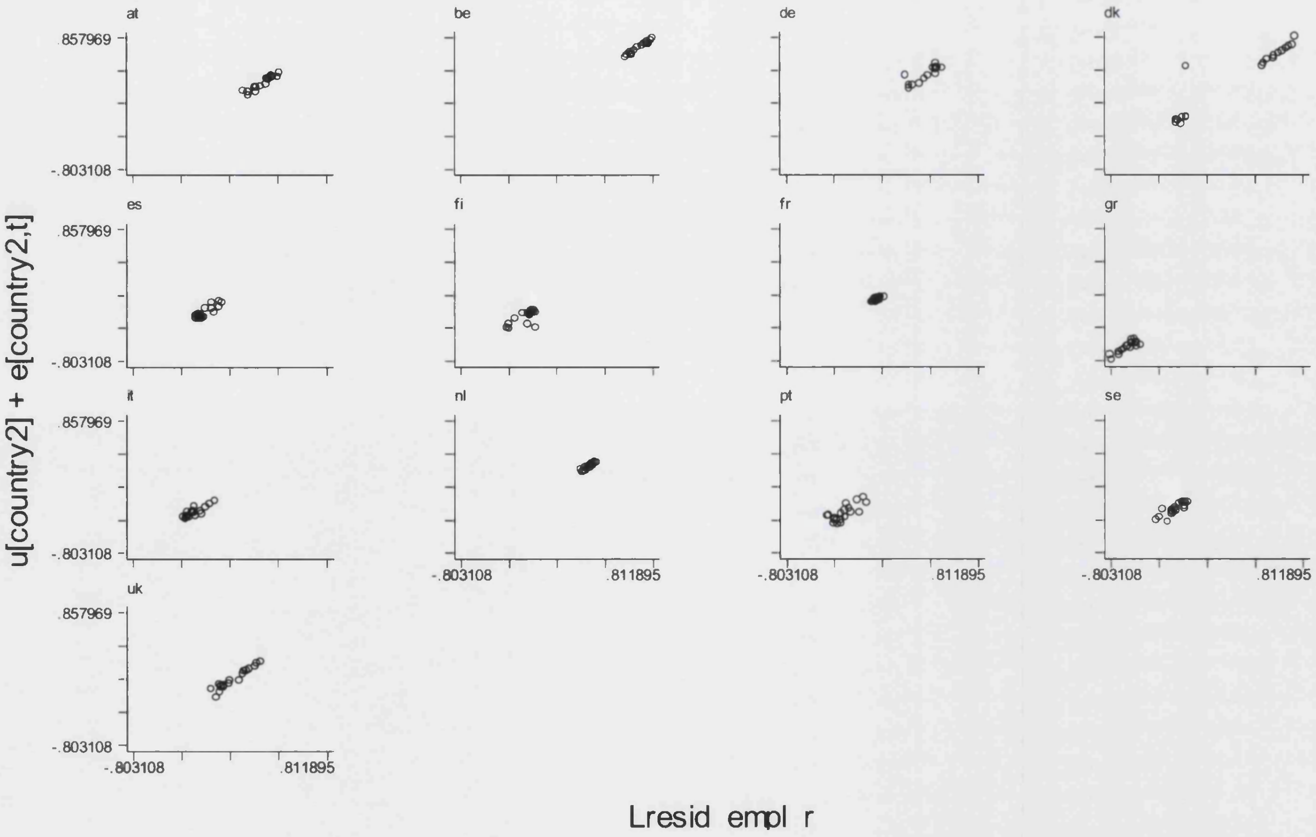
Hausman specification test

Test:	Ho: difference in coefficients not systematic
chi2(24) =	(b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
=	6.61
Prob>chi2 =	0.9997
Result:	Ho cannot be rejected. Random effects model can be used safely.

empl_r	FE	RE	Difference
tax	-0.3443	-0.2624	-0.0819
fpr	0.0247	-0.0459	0.0706
m_prod	0.0779	0.1167	-0.0388
gpi3	-0.0513	-0.0808	0.0295
year2	-0.0187	-0.0122	-0.0065
year3	-0.0258	-0.0230	-0.0028
year4	-0.0333	-0.0364	0.0031
year5	-0.0327	-0.0378	0.0051
year6	-0.0366	-0.0458	0.0092
year7	-0.0326	-0.0745	0.0419
year8	-0.0367	-0.0857	0.0491
year9	-0.0230	-0.0804	0.0574
year10	-0.0488	-0.1030	0.0542
year11	-0.0749	-0.1266	0.0517
year12	-0.0955	-0.1442	0.0486
year13	-0.1102	-0.1626	0.0524
year14	-0.1431	-0.1937	0.0506
year15	-0.1657	-0.2204	0.0547
year16	-0.1824	-0.2397	0.0573
year17	-0.1905	-0.2435	0.0530
year18	-0.2068	-0.2608	0.0540
year19	-0.2150	-0.2763	0.0613
year20	-0.2311	-0.2889	0.0578

Auto-correlation: graphical approximation

Chemical industry employees / total workforce: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

Dataset excludes Ireland

empl_r[country2,t] = Xb + u[country2] + e[country2,t]

Test:	Var(u) =	0
	chi2(1) =	1267.51
	Prob > chi2 =	0.0000

Result: Within-unit correlation cannot be ruled out

Random effects model corrected for autocorrelation

Dependent variable: empl_r
Dataset excludes Ireland

xtregar empl_r tax fpr m_prod gpi3 year2-year20

Random-effects GLS regression			Number of obs =	260	
Group variable (i) : country2			Number of groups =	13	
R-sq:	within =	0.2204	Obs per group:	min =	20
	between =	0.4597		avg =	20
	overall =	0.2961		max =	20
			Wald chi2(24) =	28.57	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.2367	

empl_r	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.0226	0.1128	-0.2000	0.8410	-0.2437	0.1985
fpr	-0.0382	0.0649	-0.5900	0.5560	-0.1654	0.0890
m_prod	0.1334	0.0717	1.8600	0.0630	-0.0071	0.2740
gpi3	-0.0095	0.0439	-0.2200	0.8290	-0.0955	0.0765
year2	-0.0181	0.0200	-0.9000	0.3660	-0.0573	0.0211
year3	-0.0335	0.0269	-1.2500	0.2130	-0.0864	0.0193
year4	-0.0545	0.0325	-1.6800	0.0930	-0.1183	0.0092
year5	-0.0606	0.0378	-1.6000	0.1090	-0.1348	0.0136
year6	-0.0692	0.0419	-1.6500	0.0990	-0.1514	0.0130
year7	-0.1054	0.0527	-2.0000	0.0460	-0.2087	-0.0021
year8	-0.1203	0.0583	-2.0600	0.0390	-0.2345	-0.0061
year9	-0.1107	0.0645	-1.7200	0.0860	-0.2371	0.0157
year10	-0.1277	0.0645	-1.9800	0.0480	-0.2541	-0.0013
year11	-0.1496	0.0638	-2.3400	0.0190	-0.2748	-0.0245
year12	-0.1718	0.0639	-2.6900	0.0070	-0.2971	-0.0464
year13	-0.1934	0.0680	-2.8500	0.0040	-0.3267	-0.0602
year14	-0.2263	0.0701	-3.2300	0.0010	-0.3637	-0.0889
year15	-0.2561	0.0746	-3.4300	0.0010	-0.4023	-0.1099
year16	-0.2724	0.0777	-3.5100	0.0000	-0.4247	-0.1201
year17	-0.2849	0.0773	-3.6900	0.0000	-0.4364	-0.1335
year18	-0.3050	0.0789	-3.8700	0.0000	-0.4595	-0.1504
year19	-0.3266	0.0825	-3.9600	0.0000	-0.4884	-0.1648
year20	-0.3419	0.0830	-4.1200	0.0000	-0.5046	-0.1792
_cons	0.1566	0.4646	0.3400	0.7360	-0.7539	1.0671
rho_ar	0.92454 (estimated autocorrelation coefficient)					
sigma_u	0.28804					
sigma_e	0.05979					
rho_fov	0.95870 (fraction of variance due to u_i)					
theta	0.61881					

Heteroskedasticity: graphical approximation

Chemical industry employees / total workforce: Predicted values against residuals

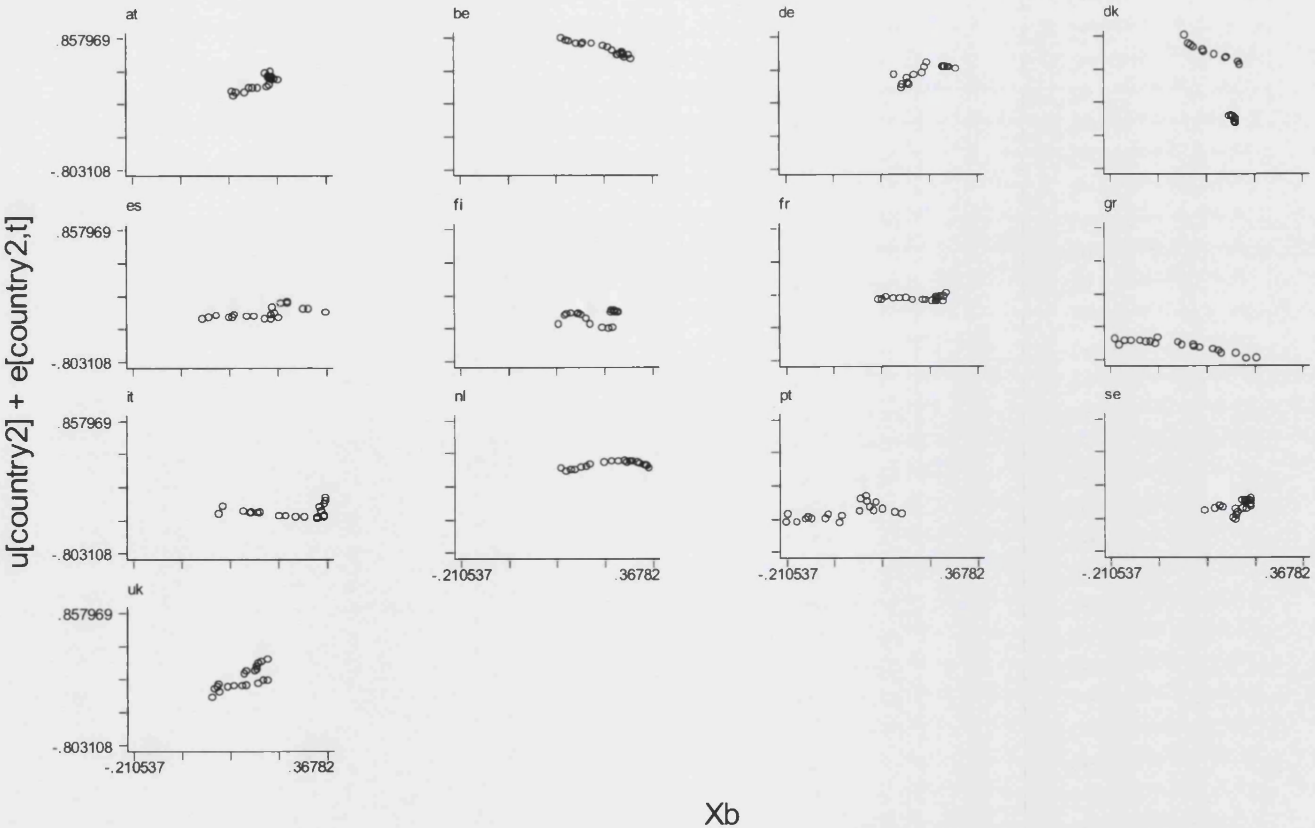


Table 48 Regression models on CI employment in absolute terms, Ireland included

Fixed effects model

Dependent variable: empl_a
Dataset includes Ireland

xtreg empl_a tax fpr m_prod gdp gpi3 year2-year20, fe

Fixed-effects (within) regression			Number of obs =	280	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.1463	Obs per group:	min =	20
	between =	0.8893		avg =	20
	overall =	0.8614		max =	20
			F(24,242) =		1.73
corr(u_i, Xb) =		0.8745	Prob > F =		0.0215

empl_a	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Int.]
tax	-0.5973	0.1483	-4.0300	0.0000	-0.8894	-0.3052
fpr	0.0894	0.1013	0.8800	0.3790	-0.1102	0.2889
m_prod	0.0011	0.1032	0.0100	0.9920	-0.2023	0.2045
gdp	0.2553	0.1046	2.4400	0.0150	0.0492	0.4614
gpi3	-0.0191	0.0746	-0.2600	0.7980	-0.1661	0.1278
year2	0.0300	0.0625	0.4800	0.6320	-0.0932	0.1532
year3	0.0444	0.0656	0.6800	0.4990	-0.0848	0.1737
year4	0.0701	0.0696	1.0100	0.3150	-0.0670	0.2072
year5	0.0957	0.0738	1.3000	0.1960	-0.0496	0.2410
year6	0.1028	0.0739	1.3900	0.1660	-0.0428	0.2485
year7	0.0834	0.0749	1.1100	0.2670	-0.0641	0.2308
year8	0.0541	0.0787	0.6900	0.4920	-0.1008	0.2090
year9	0.0678	0.0859	0.7900	0.4310	-0.1014	0.2371
year10	0.0575	0.0839	0.6900	0.4940	-0.1078	0.2227
year11	0.0008	0.0862	0.0100	0.9930	-0.1690	0.1705
year12	-0.0004	0.0854	0.0000	0.9960	-0.1687	0.1679
year13	-0.0349	0.0925	-0.3800	0.7060	-0.2171	0.1472
year14	-0.0507	0.0897	-0.5700	0.5720	-0.2274	0.1260
year15	-0.0766	0.0972	-0.7900	0.4320	-0.2680	0.1149
year16	-0.1108	0.1072	-1.0300	0.3020	-0.3220	0.1004
year17	-0.1136	0.1076	-1.0600	0.2920	-0.3255	0.0982
year18	-0.0967	0.1063	-0.9100	0.3640	-0.3061	0.1128
year19	-0.0926	0.1105	-0.8400	0.4030	-0.3103	0.1252
year20	-0.0975	0.1116	-0.8700	0.3830	-0.3173	0.1224
_cons	2.3401	1.6894	1.3900	0.1670	-0.9878	5.6680
sigma_u	0.8291					
sigma_e	0.1551					
rho	0.9662 (fraction of variance due to u_i)					

F test that all u_i=0: F(13, 242) = 67.29 Prob > F = 0.0000

Random effects model

Dependent variable: empl_a
Dataset includes Ireland

xtreg empl_a tax fpr m_prod gdp gpi3 year2-year20, re

Random-effects GLS regression			Number of obs =	280	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.1226	Obs per group:	min =	20
	between =	0.9248		avg =	20
	overall =	0.9064		max =	20
Random effects u_i ~ Gaussian			Wald chi2(24) =	135.45	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

empl_a	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Int.]
tax	-0.6970	0.1455	-4.7900	0.0000	-0.9822	-0.4118
fpr	0.1514	0.0996	1.5200	0.1290	-0.0439	0.3466
m_prod	0.1248	0.0967	1.2900	0.1970	-0.0647	0.3143
gdp	0.6596	0.0686	9.6100	0.0000	0.5251	0.7941
gpi3	0.0145	0.0740	0.2000	0.8440	-0.1304	0.1595
year2	0.0955	0.0639	1.4900	0.1350	-0.0297	0.2206
year3	0.1417	0.0656	2.1600	0.0310	0.0132	0.2703
year4	0.1988	0.0678	2.9300	0.0030	0.0660	0.3316
year5	0.2464	0.0706	3.4900	0.0000	0.1079	0.3848
year6	0.2470	0.0713	3.4600	0.0010	0.1072	0.3868
year7	0.1298	0.0757	1.7100	0.0870	-0.0186	0.2782
year8	0.0268	0.0795	0.3400	0.7360	-0.1290	0.1825
year9	0.0075	0.0857	0.0900	0.9310	-0.1606	0.1755
year10	-0.0041	0.0837	-0.0500	0.9600	-0.1681	0.1598
year11	-0.1344	0.0825	-1.6300	0.1030	-0.2961	0.0273
year12	-0.1390	0.0815	-1.7000	0.0880	-0.2988	0.0208
year13	-0.2035	0.0865	-2.3500	0.0190	-0.3729	-0.0340
year14	-0.1767	0.0862	-2.0500	0.0400	-0.3457	-0.0078
year15	-0.2305	0.0918	-2.5100	0.0120	-0.4105	-0.0506
year16	-0.3253	0.0974	-3.3400	0.0010	-0.5163	-0.1344
year17	-0.3365	0.0970	-3.4700	0.0010	-0.5266	-0.1463
year18	-0.3001	0.0973	-3.0800	0.0020	-0.4909	-0.1093
year19	-0.3026	0.1013	-2.9900	0.0030	-0.5010	-0.1041
year20	-0.3125	0.1018	-3.0700	0.0020	-0.5120	-0.1129
_cons	-3.2607	1.2513	-2.6100	0.0090	-5.7132	-0.8081
sigma_u	0.344624					
sigma_e	0.155115					
rho	0.831539 (fraction of variance due to u_i)					

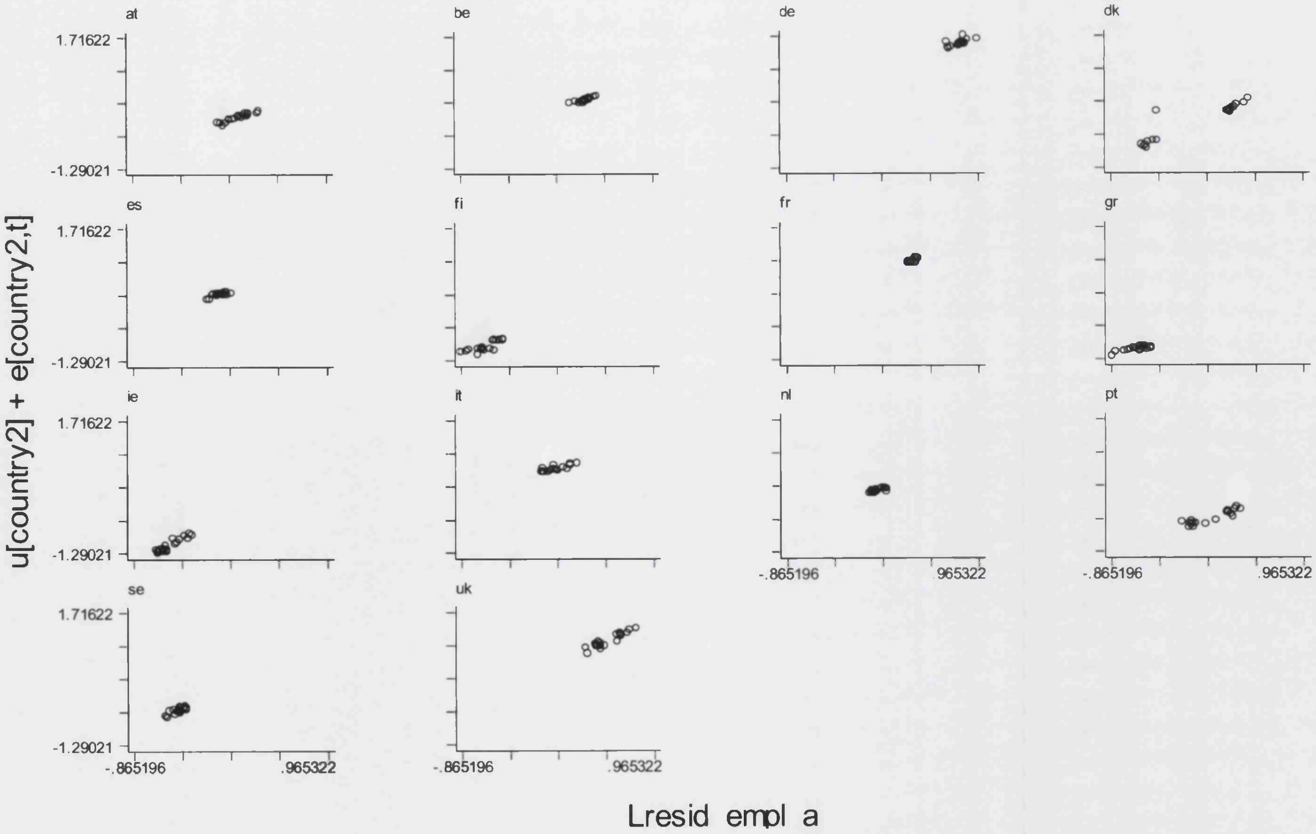
Hausman specification test

Test:	Ho: difference in coefficients not systematic
chi2(24) =	(b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
=	34.22
Prob>chi2 =	0.0808
Result:	Ho cannot be rejected at 10 percent level.
	Ho rejected at 1 percent level.
	RE model cannot be used safely.

empl_a	FE	RE	Difference
tax	-0.5973	-0.6970	0.0997
fpr	0.0894	0.1514	-0.0620
m_prod	0.0011	0.1248	-0.1237
gdp	0.2553	0.6596	-0.4043
gpi3	-0.0191	0.0145	-0.0337
year2	0.0300	0.0955	-0.0655
year3	0.0444	0.1417	-0.0973
year4	0.0701	0.1988	-0.1287
year5	0.0957	0.2464	-0.1507
year6	0.1028	0.2470	-0.1442
year7	0.0834	0.1298	-0.0464
year8	0.0541	0.0268	0.0273
year9	0.0678	0.0075	0.0604
year10	0.0575	-0.0041	0.0616
year11	0.0008	-0.1344	0.1352
year12	-0.0004	-0.1390	0.1386
year13	-0.0349	-0.2035	0.1685
year14	-0.0507	-0.1767	0.1260
year15	-0.0766	-0.2305	0.1540
year16	-0.1108	-0.3253	0.2146
year17	-0.1136	-0.3365	0.2228
year18	-0.0967	-0.3001	0.2035
year19	-0.0926	-0.3026	0.2100
year20	-0.0975	-0.3125	0.2150

Auto-correlation: graphical approximation

Chemical industry employees in absolute terms: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

not possible, as this is a fixed effects regression model

Fixed effects model corrected for autocorrelation

Dependent variable: empl_a
Dataset includes Ireland

xtregar empl_a tax fpr m_prod gdp gpi3 year2-year20, fe

Fixed effects (within) regression			Number of obs =	266	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.0889	Obs per group:	min =	19
	between =	0.5572		avg =	19
	overall =	0.4182		max =	19
			F (23,229)		0.97
corr(u_i, X) =		0.6196	Prob > chi2 =		0.5035

empl_a	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.0298	0.1115	-0.2700	0.7900	-0.2494	0.1899
fpr	0.0428	0.0583	0.7400	0.4630	-0.0720	0.1577
m_prod	0.1278	0.0825	1.5500	0.1230	-0.0347	0.2903
gdp	0.0476	0.0890	0.5300	0.5940	-0.1278	0.2229
gpi3	-0.0198	0.0486	-0.4100	0.6840	-0.1156	0.0760
year2	-0.0032	0.0268	-0.1200	0.9060	-0.0559	0.0496
year3	-0.0065	0.0388	-0.1700	0.8680	-0.0829	0.0699
year4	-0.0054	0.0491	-0.1100	0.9130	-0.1022	0.0914
year5	0.0067	0.0583	0.1100	0.9090	-0.1082	0.1216
year6	0.0238	0.0608	0.3900	0.6960	-0.0960	0.1436
year7	0.0328	0.0451	0.7300	0.4680	-0.0561	0.1218
year8	0.0377	0.0390	0.9700	0.3350	-0.0392	0.1145
year9	0.0762	0.0397	1.9200	0.0560	-0.0019	0.1544
year10	0.0871	0.0393	2.2100	0.0280	0.0096	0.1646
year11	0.0793	0.0354	2.2400	0.0260	0.0096	0.1490
year12	0.0861	0.0349	2.4700	0.0140	0.0174	0.1548
year13	0.0612	0.0338	1.8100	0.0720	-0.0054	0.1277
year14	0.0252	0.0334	0.7600	0.4500	-0.0405	0.0910
year15	0.0035	0.0308	0.1100	0.9100	-0.0571	0.0641
year16	0.0050	0.0288	0.1700	0.8620	-0.0518	0.0618
year17	0.0029	0.0254	0.1200	0.9080	-0.0470	0.0529
year18	0.0077	0.0209	0.3700	0.7120	-0.0334	0.0489
year19	0.0035	0.0157	0.2200	0.8260	-0.0275	0.0345
year20	(dropped)					
_cons	3.0413	0.0971	31.3100	0.0000	2.8500	3.2327
rho_ar	0.929878 (estimated autocorrelation coefficient)					
sigma_u	1.07408					
sigma_e	0.056424					
rho_fov	0.997248 (fraction of variance due to u_i)					

F test that all u_i=0: F(13, 229) = 12.01 Prob > F = 0.0000

Heteroskedasticity: graphical approximation

Chemical industry employees in absolute terms: Predicted values against residuals

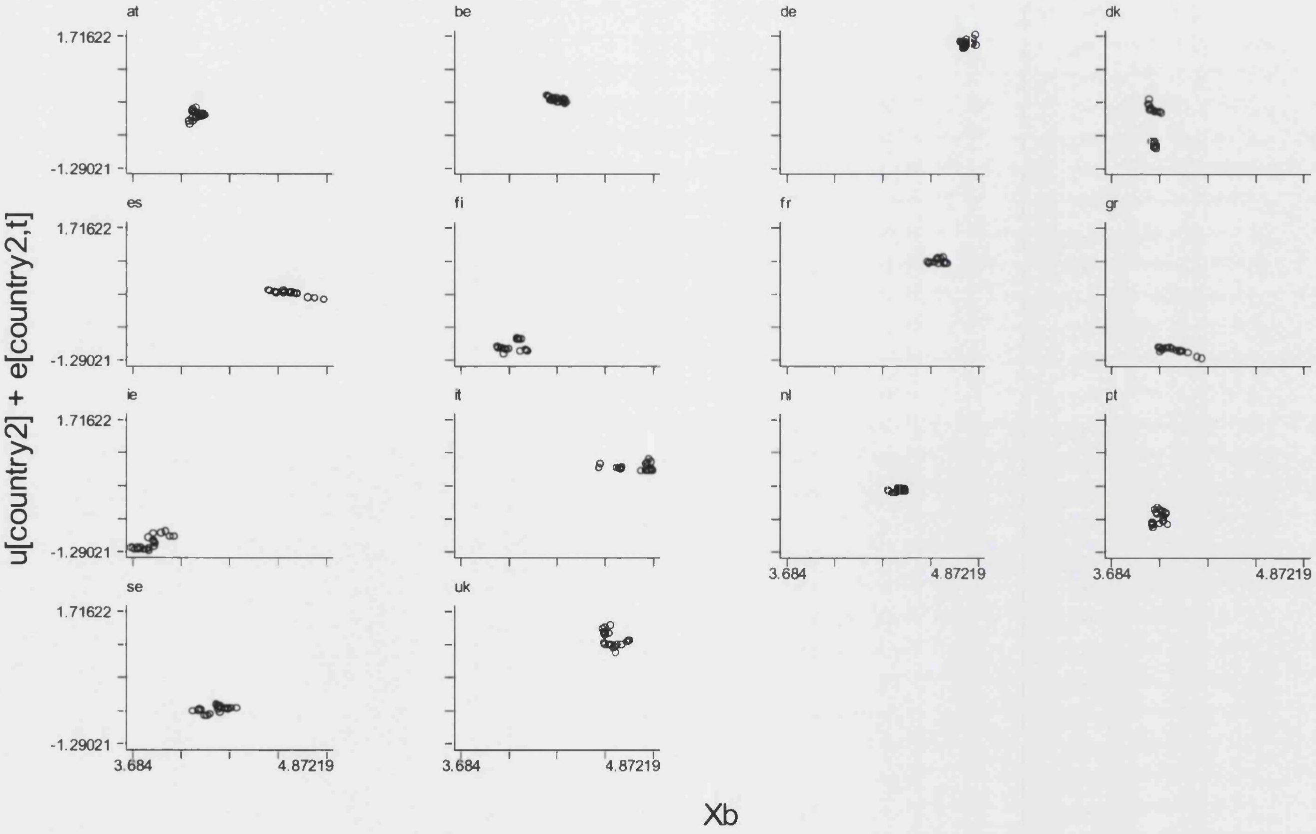


Table 49 Regression models on CI employment in absolute terms, Ireland excluded

Fixed effects model

Dependent variable: empl_a
Dataset excludes Ireland

xtreg empl_a tax fpr m_prod gdp gpi3 year2-year20, fe

Fixed-effects (within) regression			Number of obs =	260	
Group variable (i) : country2			Number of groups =	13	
R-sq:	within =	0.1409	Obs per group:	min =	20
	between =	0.083		avg =	20
	overall =	0.0129		max =	20
			F(24,223) =	1.52	
corr(u_i, Xb) =		-0.1787	Prob > F =	0.0611	

empl_a	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Int.]
tax	-0.1354	0.1750	-0.7700	0.4400	-0.4803	0.2096
fpr	-0.0427	0.1052	-0.4100	0.6850	-0.2501	0.1646
m_prod	-0.0726	0.1034	-0.7000	0.4830	-0.2764	0.1312
gdp	-0.0269	0.1195	-0.2200	0.8220	-0.2624	0.2087
gpi3	-0.1334	0.0783	-1.7000	0.0900	-0.2878	0.0210
year2	-0.0112	0.0642	-0.1700	0.8620	-0.1376	0.1153
year3	-0.0221	0.0684	-0.3200	0.7470	-0.1570	0.1127
year4	-0.0347	0.0740	-0.4700	0.6390	-0.1805	0.1111
year5	-0.0297	0.0793	-0.3700	0.7090	-0.1859	0.1266
year6	-0.0194	0.0795	-0.2400	0.8080	-0.1761	0.1373
year7	-0.0192	0.0789	-0.2400	0.8080	-0.1747	0.1362
year8	-0.0091	0.0805	-0.1100	0.9100	-0.1678	0.1496
year9	0.0254	0.0867	0.2900	0.7700	-0.1455	0.1963
year10	0.0219	0.0845	0.2600	0.7960	-0.1446	0.1884
year11	0.0118	0.0865	0.1400	0.8920	-0.1587	0.1822
year12	0.0099	0.0860	0.1100	0.9090	-0.1597	0.1795
year13	-0.0098	0.0929	-0.1100	0.9160	-0.1930	0.1733
year14	-0.0530	0.0898	-0.5900	0.5560	-0.2299	0.1240
year15	-0.0682	0.0972	-0.7000	0.4830	-0.2598	0.1233
year16	-0.0651	0.1077	-0.6000	0.5460	-0.2774	0.1472
year17	-0.0660	0.1083	-0.6100	0.5430	-0.2794	0.1474
year18	-0.0710	0.1060	-0.6700	0.5040	-0.2799	0.1379
year19	-0.0691	0.1097	-0.6300	0.5290	-0.2853	0.1470
year20	-0.0680	0.1107	-0.6100	0.5400	-0.2863	0.1502
_cons	6.2379	1.8719	3.3300	0.0010	2.5491	9.9268
sigma_u	1.0943					
sigma_e	0.1520					
rho	0.9811 (fraction of variance due to u_i)					

F test that all u_i=0: F(12,223) = 72.61 Prob > F = 0.0000

Random effects model

Dependent variable: empl_a
Dataset excludes Ireland

xtreg empl_a tax fpr m_prod gdp gpi3 year2-year20, re

Random-effects GLS regression			Number of obs =	260	
Group variable (i) : country2			Number of groups =	13	
R-sq:	within =	0.0815	Obs per group:	min =	20
	between =	0.9105		avg =	20
	overall =	0.8888		max =	20
Random effects u_i ~ Gaussian			Wald chi2(24) =	95.29	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

empl_a	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Int.]
tax	-0.5142	0.1660	-3.1000	0.0020	-0.8396	-0.1888
fpr	0.1270	0.1040	1.2200	0.2220	-0.0769	0.3309
m_prod	0.1473	0.0994	1.4800	0.1380	-0.0476	0.3422
gdp	0.5820	0.0763	7.6300	0.0000	0.4325	0.7315
gpi3	-0.0116	0.0782	-0.1500	0.8820	-0.1648	0.1417
year2	0.0791	0.0676	1.1700	0.2420	-0.0534	0.2116
year3	0.1194	0.0701	1.7000	0.0880	-0.0179	0.2567
year4	0.1599	0.0730	2.1900	0.0290	0.0168	0.3030
year5	0.1990	0.0767	2.5900	0.0090	0.0487	0.3492
year6	0.2010	0.0776	2.5900	0.0100	0.0490	0.3531
year7	0.0897	0.0810	1.1100	0.2680	-0.0691	0.2485
year8	-0.0041	0.0841	-0.0500	0.9610	-0.1690	0.1607
year9	-0.0176	0.0898	-0.2000	0.8440	-0.1936	0.1583
year10	-0.0300	0.0875	-0.3400	0.7320	-0.2015	0.1415
year11	-0.1501	0.0860	-1.7500	0.0810	-0.3187	0.0185
year12	-0.1614	0.0852	-1.9000	0.0580	-0.3283	0.0055
year13	-0.2249	0.0899	-2.5000	0.0120	-0.4011	-0.0488
year14	-0.2092	0.0898	-2.3300	0.0200	-0.3851	-0.0333
year15	-0.2664	0.0953	-2.8000	0.0050	-0.4531	-0.0796
year16	-0.3553	0.1006	-3.5300	0.0000	-0.5524	-0.1581
year17	-0.3664	0.1006	-3.6400	0.0000	-0.5636	-0.1692
year18	-0.3356	0.1007	-3.3300	0.0010	-0.5330	-0.1382
year19	-0.3324	0.1046	-3.1800	0.0010	-0.5375	-0.1273
year20	-0.3413	0.1052	-3.2400	0.0010	-0.5475	-0.1350
_cons	-2.5304	1.3151	-1.9200	0.0540	-5.1079	0.0471
sigma_u	0.333153					
sigma_e	0.152001					
rho	0.827702 (fraction of variance due to u_i)					

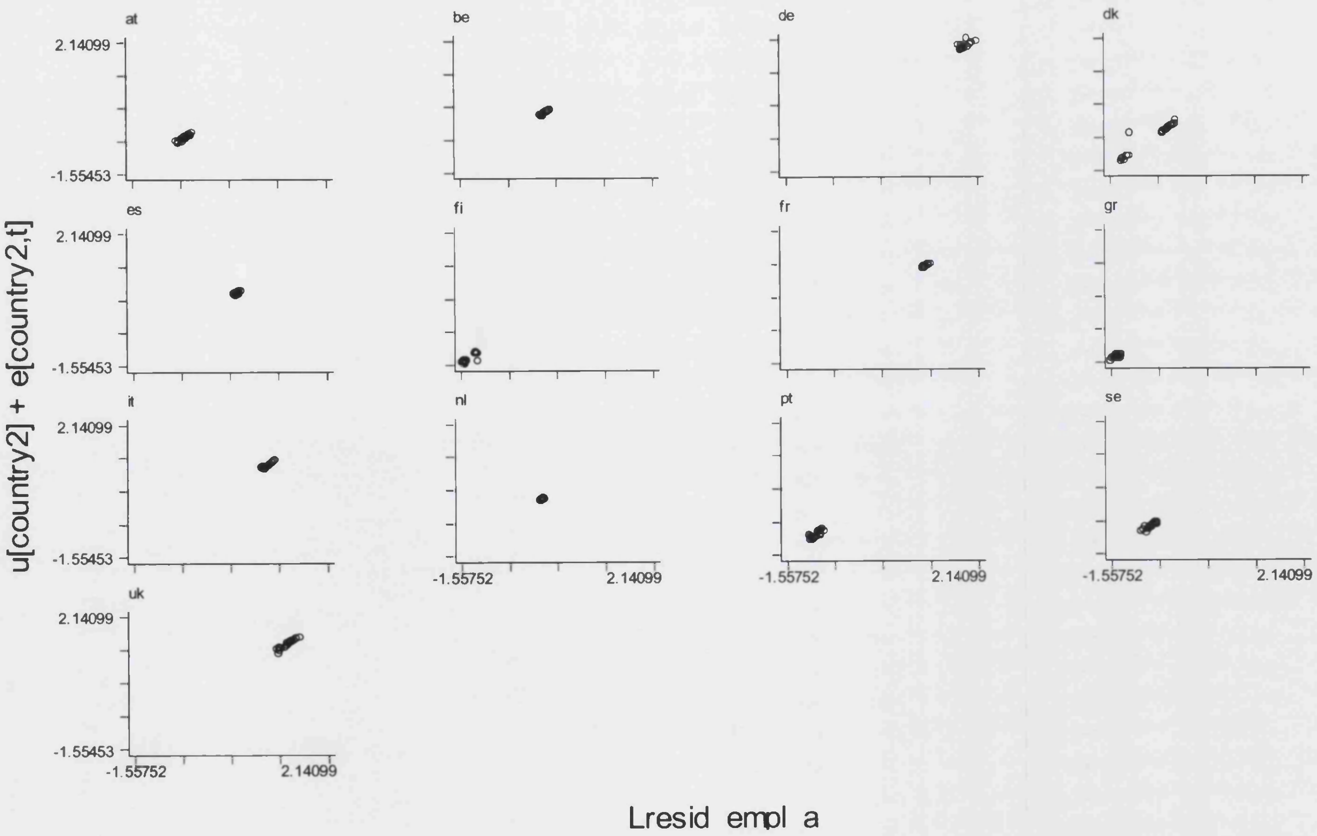
Hausman specification test

Test:	Ho: difference in coefficients not systematic
chi2(24) =	(b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
=	43.77
Prob>chi2 =	0.0081
Result:	Ho cannot be rejected at 10 percent level. Ho rejected at 1 percent level. RE model <u>cannot</u> be used safely.

empl_a	FE	RE	Difference
tax	-0.1354	-0.5142	0.3788
fpr	-0.0427	0.1270	-0.1697
m_prod	-0.0726	0.1473	-0.2199
gdp	-0.0269	0.5820	-0.6088
gpi3	-0.1334	-0.0116	-0.1218
year2	-0.0112	0.0791	-0.0902
year3	-0.0221	0.1194	-0.1415
year4	-0.0347	0.1599	-0.1946
year5	-0.0297	0.1990	-0.2286
year6	-0.0194	0.2010	-0.2204
year7	-0.0192	0.0897	-0.1089
year8	-0.0091	-0.0041	-0.0049
year9	0.0254	-0.0176	0.0430
year10	0.0219	-0.0300	0.0519
year11	0.0118	-0.1501	0.1619
year12	0.0099	-0.1614	0.1713
year13	-0.0098	-0.2249	0.2151
year14	-0.0530	-0.2092	0.1562
year15	-0.0682	-0.2664	0.1981
year16	-0.0651	-0.3553	0.2902
year17	-0.0660	-0.3664	0.3004
year18	-0.0710	-0.3356	0.2646
year19	-0.0691	-0.3324	0.2632
year20	-0.0680	-0.3413	0.2732

Auto-correlation: graphical approximation

Chemical industry employees in absolute terms: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

not possible, as this is a fixed effects regression model

Fixed effects model corrected for autocorrelation

Dependent variable: empl_a
Dataset excludes Ireland

xtregar empl_a tax fpr m_prod gdp gpi3 year2-year20, fe

Fixed effects (within) regression			Number of obs =	247
Group variable (i) : country2			Number of groups =	13
R-sq:	within =	0.1032	Obs per group:	min = 19
	between =	0.3319		avg = 19
	overall =	0.2169		max = 19
			F (23,211)	1.06
corr(u_i, X) =		0.4294	Prob > chi2 =	0.3982

empl_a	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	0.0157	0.1168	0.1300	0.8930	-0.2146	0.2460
fpr	0.0192	0.0626	0.3100	0.7590	-0.1042	0.1426
m_prod	0.1321	0.0842	1.5700	0.1180	-0.0338	0.2980
gdp	0.0202	0.0928	0.2200	0.8280	-0.1627	0.2030
gpi3	-0.0245	0.0495	-0.4900	0.6220	-0.1220	0.0731
year2	-0.0013	0.0283	-0.0500	0.9640	-0.0571	0.0545
year3	0.0009	0.0409	0.0200	0.9830	-0.0798	0.0815
year4	-0.0008	0.0515	-0.0200	0.9880	-0.1023	0.1007
year5	0.0136	0.0610	0.2200	0.8240	-0.1066	0.1338
year6	0.0340	0.0635	0.5400	0.5930	-0.0911	0.1591
year7	0.0413	0.0467	0.8800	0.3780	-0.0508	0.1333
year8	0.0516	0.0404	1.2800	0.2030	-0.0280	0.1313
year9	0.0952	0.0410	2.3200	0.0210	0.0144	0.1760
year10	0.1057	0.0406	2.6000	0.0100	0.0256	0.1858
year11	0.1003	0.0369	2.7200	0.0070	0.0275	0.1730
year12	0.1027	0.0363	2.8300	0.0050	0.0312	0.1742
year13	0.0768	0.0353	2.1800	0.0310	0.0072	0.1464
year14	0.0339	0.0343	0.9900	0.3240	-0.0337	0.1016
year15	0.0096	0.0317	0.3000	0.7630	-0.0530	0.0721
year16	0.0086	0.0303	0.2800	0.7770	-0.0512	0.0684
year17	0.0035	0.0268	0.1300	0.8950	-0.0492	0.0563
year18	0.0022	0.0218	0.1000	0.9180	-0.0407	0.0452
year19	0.0037	0.0165	0.2300	0.8220	-0.0287	0.0362
year20	(dropped)					
_cons	3.4886	0.1110	31.4200	0.0000	3.2697	3.7075
rho_ar	0.922837 (estimated autocorrelation coefficient)					
sigma_u	1.038654					
sigma_e	0.056461					
rho_fov	0.997054 (fraction of variance due to u_i)					

F test that all u_i=0: F(12, 211) = 13.4 Prob > F = 0.0000

Heteroskedasticity: graphical approximation

Chemical industry employees in absolute terms: Predicted values against residuals

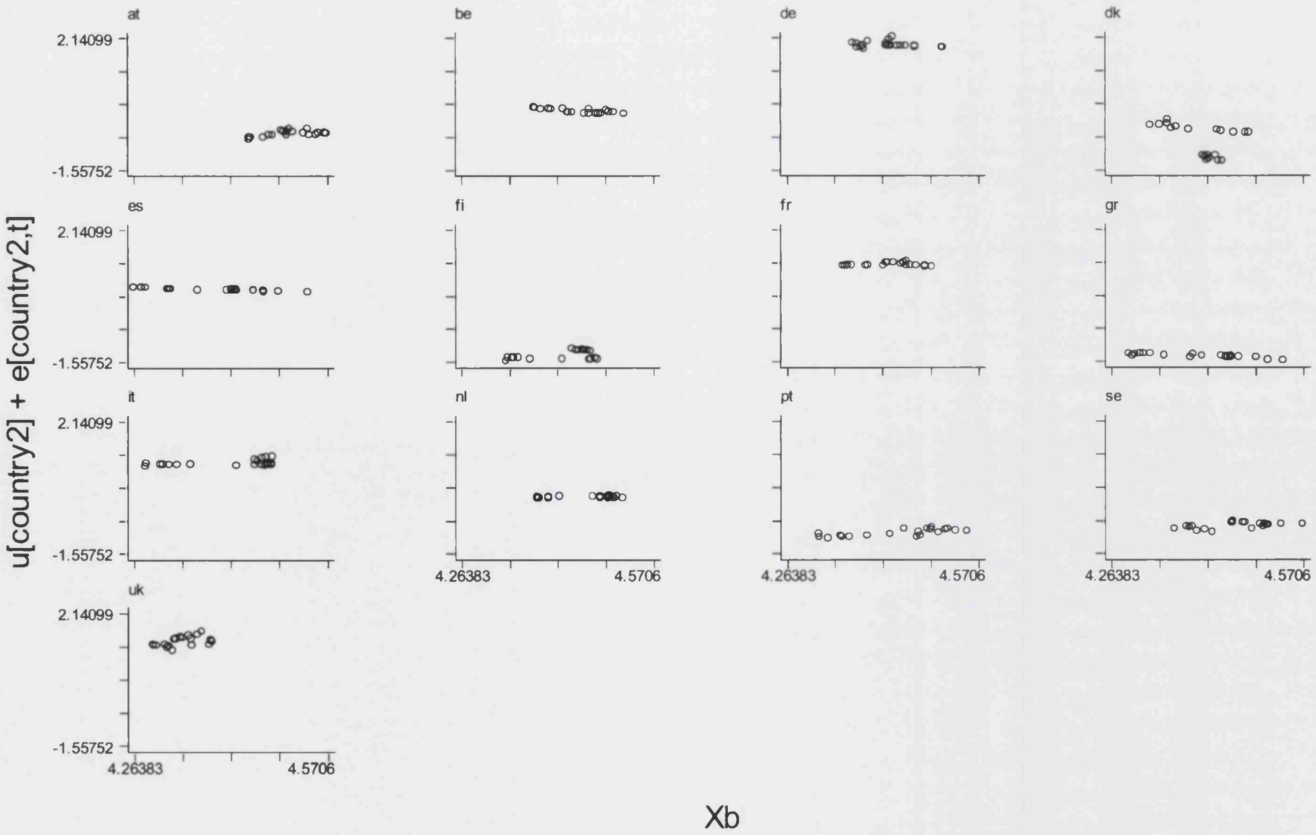


Table 50 Regression models on CI intra-EU exports / GDP, Ireland included

Fixed effects model

Dependent variable: exp_r
Dataset includes Ireland

xtreg exp_r_r tax fpr m_prod gdp gpi3 year12-year19, fe

Fixed-effects (within) regression			Number of obs =	126	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.7985	Obs per group:	min =	9
	between =	0.2202		avg =	9
	overall =	0.2314		max =	9
			F(12,100) =	33.02	
corr(u_i, Xb) =		0.1842	Prob > F =	0.0000	

exp_r	Coef.	Std.	Err.	t	P>|t|	[95% Conf. Int.]
tax	-0.6433	0.3376	-1.9100	0.0600	-1.3132	0.0266
fpr	0.0828	0.1617	0.5100	0.6100	-0.2380	0.4036
m_prod	0.6074	0.2547	2.3800	0.0190	0.1021	1.1126
gpi3	0.3278	0.1013	3.2300	0.0020	0.1267	0.5288
year12	0.0313	0.0456	0.6900	0.4940	-0.0592	0.1219
year13	-0.0184	0.0479	-0.3800	0.7020	-0.1134	0.0766
year14	0.0535	0.0556	0.9600	0.3390	-0.0569	0.1638
year15	0.1555	0.0664	2.3400	0.0210	0.0237	0.2872
year16	0.1802	0.0751	2.4000	0.0180	0.0312	0.3292
year17	0.2054	0.0798	2.5700	0.0120	0.0470	0.3637
year18	0.3448	0.0839	4.1100	0.0000	0.1783	0.5114
year19	0.3962	0.0873	4.5400	0.0000	0.2231	0.5693
_cons	-7.3108	1.5355	-4.7600	0.0000	-10.3572	-4.2644
sigma_u	0.912755					
sigma_e	0.119236					
rho	0.983221 (fraction of variance due to u_i)					

F test that all u_i=0: F(13,100) = 420.11 Prob > F = 0.0000

Random effects model

Dependent variable: exp_r
Dataset includes Ireland

xtreg exp_r tax fpr m_prod gdp gpi3 year12-year19, re

Random-effects GLS regression			Number of obs =	126	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.7978	Obs per group:	min =	9
	between =	0.2853		avg =	9
	overall =	0.2948		max =	9
Random effects u_i ~ Gaussian			Wald chi2(12) =	406.56	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

exp_r	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.6131	0.3285	-1.8700	0.0620	-1.2569	0.0308
fpr	0.0801	0.1580	0.5100	0.6120	-0.2295	0.3897
m_prod	0.7466	0.2305	3.2400	0.0010	0.2948	1.1984
gpi3	0.2965	0.0972	3.0500	0.0020	0.1059	0.4871
year12	0.0327	0.0452	0.7200	0.4690	-0.0559	0.1213
year13	-0.0255	0.0471	-0.5400	0.5890	-0.1179	0.0669
year14	0.0394	0.0540	0.7300	0.4650	-0.0664	0.1453
year15	0.1319	0.0633	2.0800	0.0370	0.0078	0.2560
year16	0.1497	0.0708	2.1100	0.0350	0.0109	0.2885
year17	0.1758	0.0757	2.3200	0.0200	0.0273	0.3242
year18	0.3123	0.0794	3.9300	0.0000	0.1567	0.4678
year19	0.3591	0.0818	4.3900	0.0000	0.1987	0.5195
_cons	-7.7228	1.5016	-5.1400	0.0000	-10.6659	-4.7797
sigma_u	0.977267					
sigma_e	0.119236					
rho	0.985332 (fraction of variance due to u_i)					

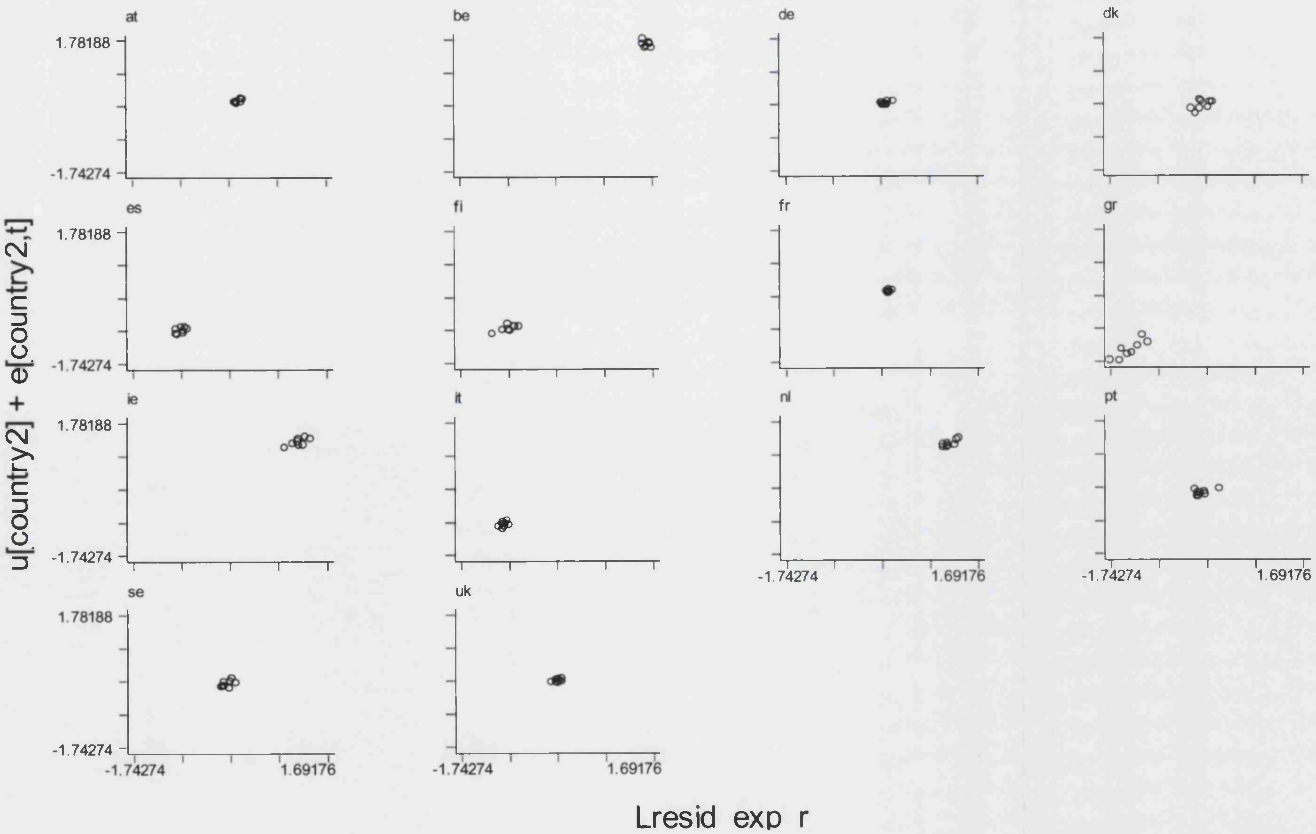
Hausman specification test

Test:	Ho: difference in coefficients not systematic
chi2(24) =	(b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
=	1.73
Prob>chi2 =	0.9997
Result:	Ho cannot be rejected. Random effects model can be used safely.

exp_r	FE	RE	Difference
tax	-0.6433	-0.6131	-0.0302
fpr	0.0828	0.0801	0.0027
m_prod	0.6074	0.7466	-0.1392
gpi3	0.3278	0.2965	0.0313
year12	0.0313	0.0327	-0.0014
year13	-0.0184	-0.0255	0.0071
year14	0.0535	0.0394	0.0140
year15	0.1555	0.1319	0.0236
year16	0.1802	0.1497	0.0306
year17	0.2054	0.1758	0.0296
year18	0.3448	0.3123	0.0326
year19	0.3962	0.3591	0.0371

Auto-correlation: graphical approximation

Intra-EU exports / GDP: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

Dataset includes Ireland

exp_r[country2,t] = Xb + u[country2] + e[country2,t]

Test:	Var(u) =	0
	chi2(1) =	481.64
	Prob > chi2 =	0.0000

Result: Within-unit correlation cannot be ruled out

Random effects model corrected for autocorrelation

Dependent variable: exp_r
Dataset includes Ireland

xtregar exp_r tax fpr m_prod gpi3 year12-year19

Random-effects GLS regression			Number of obs =	126	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.7921	Obs per group:	min =	9
	between =	0.2639		avg =	9
	overall =	0.2324		max =	9
			Wald chi2(24) =	189.47	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

exp_r	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.2414	0.2788	-0.8700	0.3860	-0.7878	0.3049
fpr	-0.1554	0.1457	-1.0700	0.2860	-0.4411	0.1302
m_prod	0.4429	0.1859	2.3800	0.0170	0.0786	0.8073
gpi3	0.2646	0.1023	2.5900	0.0100	0.0641	0.4651
year12	0.0391	0.0276	1.4100	0.1580	-0.0151	0.0932
year13	-0.0063	0.0372	-0.1700	0.8660	-0.0793	0.0667
year14	0.0884	0.0469	1.8900	0.0590	-0.0034	0.1803
year15	0.1961	0.0563	3.4800	0.0000	0.0857	0.3066
year16	0.2297	0.0636	3.6100	0.0000	0.1050	0.3544
year17	0.2694	0.0675	3.9900	0.0000	0.1372	0.4017
year18	0.4086	0.0708	5.7700	0.0000	0.2698	0.5473
year19	0.4399	0.0737	5.9700	0.0000	0.2954	0.5844
_cons	-6.3250	1.2482	-5.0700	0.0000	-8.7714	-3.8786
rho_ar	0.73350 (estimated autocorrelation coefficient)					
sigma_u	0.78673					
sigma_e	0.09592					
rho_fov	0.98535 (fraction of variance due to u_i)					
theta	0.88073					

Heteroskedasticity: graphical approximation

Intra-EU exports / GDP: Predicted values against residuals

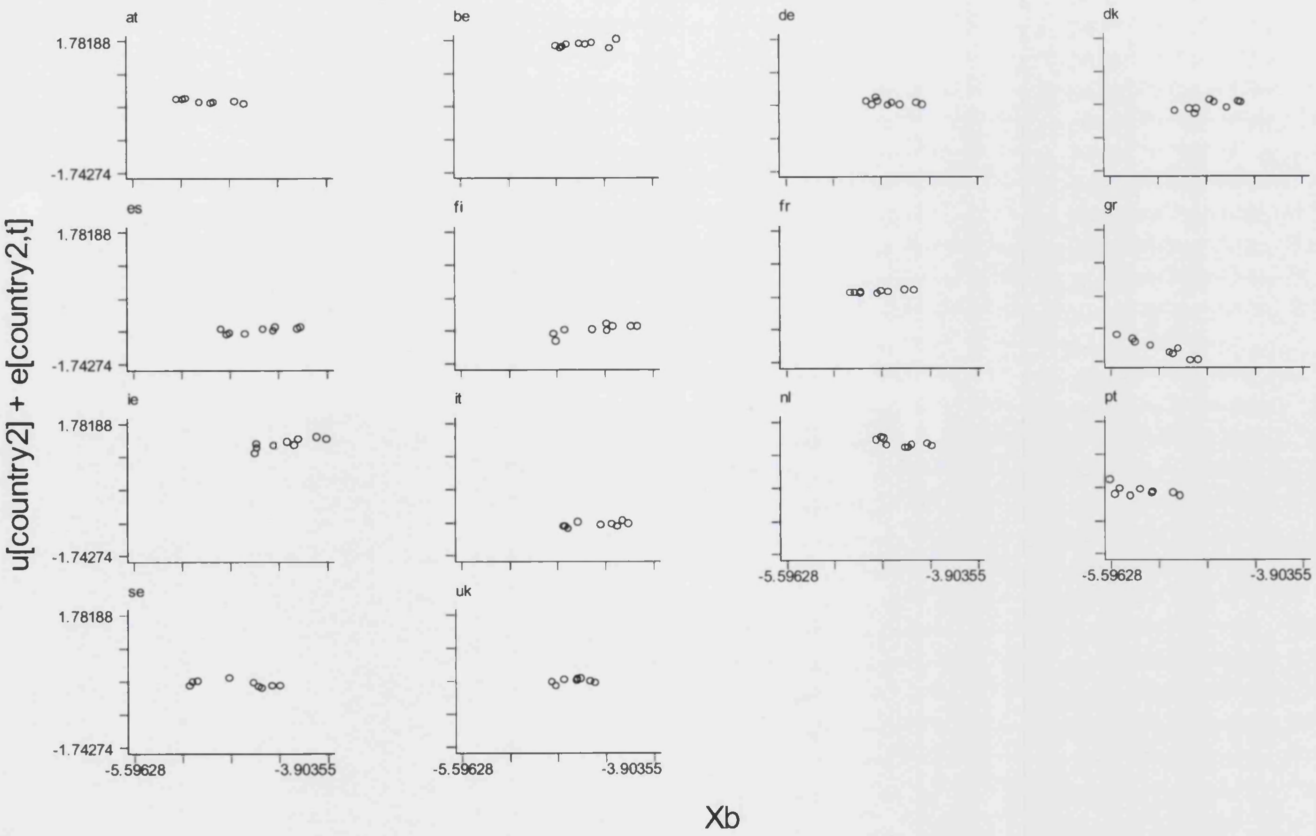


Table 51 Regression models on CI intra-EU exports / GDP, Ireland excluded

Fixed effects model

Dependent variable: exp_r
Dataset excludes Ireland

xtreg exp_r_r tax fpr m_prod gdp gpi3 year12-year19, fe

Fixed-effects (within) regression		Number of obs =	117	
Group variable (i) : country2		Number of groups =	13	
R-sq: within =	0.7959	Obs per group:	min =	9
between =	0.1886		avg =	9
overall =	0.2202		max =	9
		F(12,92) =		29.9
corr(u_i, Xb) =	0.1171	Prob > F =		0.0000

exp_r	Coef.	Std. Err.	t	P>|t|	[95% Conf. Int.]	
tax	-0.0628	0.3738	-0.1700	0.8670	-0.8052	0.6795
fpr	-0.0355	0.1699	-0.2100	0.8350	-0.3730	0.3019
m_prod	0.7640	0.2533	3.0200	0.0030	0.2608	1.2671
gpi3	0.3120	0.0987	3.1600	0.0020	0.1159	0.5081
year12	0.0201	0.0461	0.4400	0.6640	-0.0716	0.1117
year13	-0.0523	0.0490	-1.0700	0.2880	-0.1496	0.0450
year14	0.0208	0.0569	0.3700	0.7160	-0.0923	0.1339
year15	0.0994	0.0680	1.4600	0.1470	-0.0357	0.2345
year16	0.1275	0.0765	1.6700	0.0990	-0.0244	0.2795
year17	0.1380	0.0808	1.7100	0.0910	-0.0225	0.2985
year18	0.2639	0.0860	3.0700	0.0030	0.0932	0.4346
year19	0.2947	0.0914	3.2300	0.0020	0.1133	0.4762
_cons	-8.8049	1.5716	-5.6000	0.0000	-11.9263	-5.6835
sigma_u	0.835871					
sigma_e	0.115921					
rho	0.98113 (fraction of variance due to u_i)					

F test that all u_i=0: F(12,92) = 332.82 Prob > F = 0.0000

Random effects model

Dependent variable: exp_r
Dataset excludes Ireland

xtreg exp_r tax fpr m_prod gdp gpi3 year12-year19, re

Random-effects GLS regression		Number of obs =	117	
Group variable (i) : country2		Number of groups =	13	
R-sq: within =	0.7954	Obs per group:	min =	9
between =	0.2207		avg =	9
overall =	0.2532		max =	9
Random effects u_i ~ Gaussian		Wald chi2(12) =		363.05
corr(u_i, X) = 0 (assumed)		Prob > chi2 =		0.0000

exp_r	Coef.	Std. Err.	z	P>|z|	[95% Conf. Int.]	
tax	-0.0575	0.3611	-0.1600	0.8730	-0.7653	0.6503
fpr	-0.0495	0.1664	-0.3000	0.7660	-0.3755	0.2766
m_prod	0.8563	0.2264	3.7800	0.0000	0.4125	1.3000
gpi3	0.2770	0.0948	2.9200	0.0030	0.0912	0.4627
year12	0.0216	0.0460	0.4700	0.6390	-0.0686	0.1118
year13	-0.0564	0.0484	-1.1600	0.2450	-0.1513	0.0386
year14	0.0130	0.0555	0.2300	0.8150	-0.0958	0.1218
year15	0.0851	0.0649	1.3100	0.1900	-0.0421	0.2123
year16	0.1080	0.0720	1.5000	0.1330	-0.0330	0.2491
year17	0.1207	0.0766	1.5800	0.1150	-0.0295	0.2710
year18	0.2449	0.0812	3.0200	0.0030	0.0858	0.4040
year19	0.2722	0.0853	3.1900	0.0010	0.1050	0.4393
_cons	-8.9116	1.5382	-5.7900	0.0000	-11.9265	-5.8968
sigma_u	0.839644					
sigma_e	0.115921					
rho	0.981296 (fraction of variance due to u_i)					

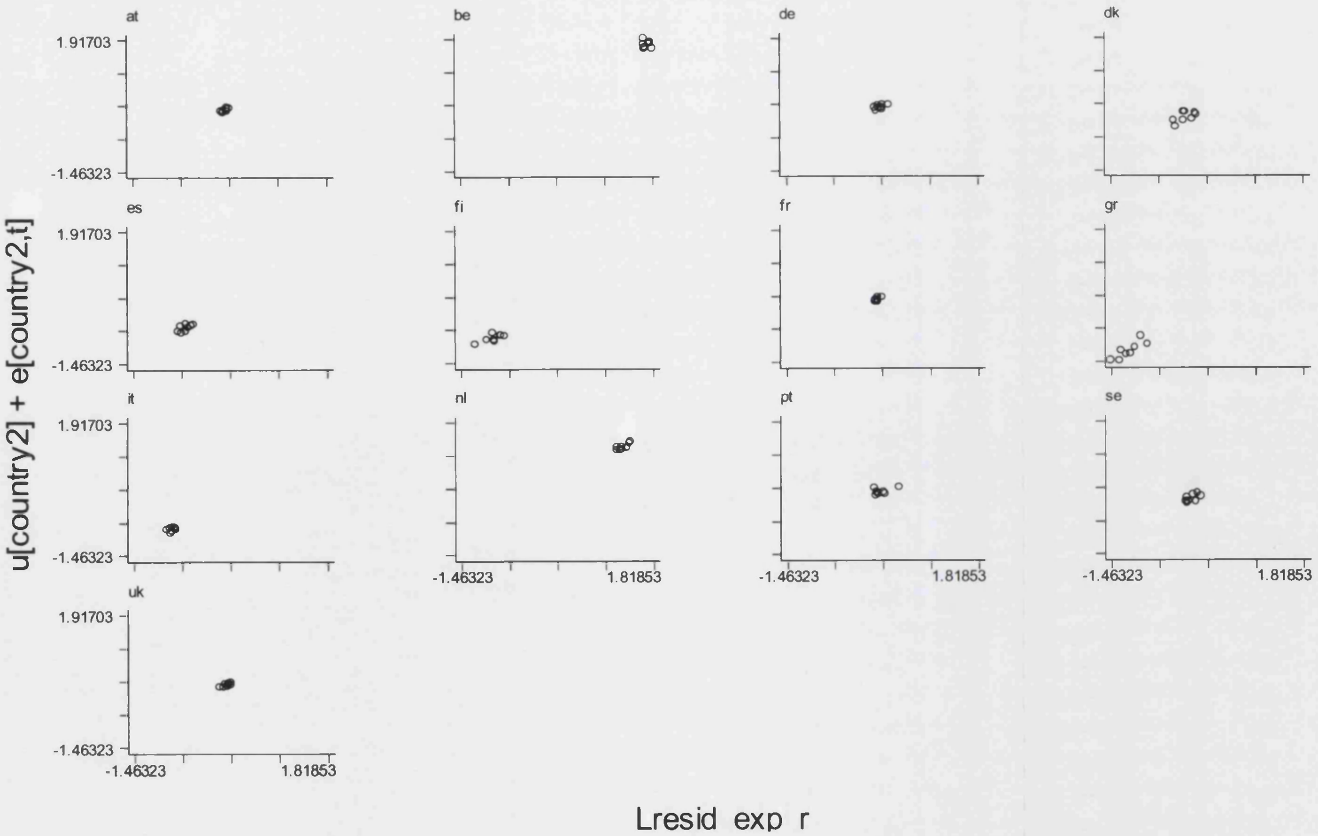
Hausman specification test

Test:	Ho: difference in coefficients not systematic
chi2(24) =	(b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
=	2.82
Prob>chi2 =	0.9967
Result:	Ho cannot be rejected. Random effects model can be used safely.

exp_r	FE	RE	Difference
tax	-0.0628	-0.0575	-0.0053
fpr	-0.0355	-0.0495	0.0140
m_prod	0.7640	0.8563	-0.0923
gpi3	0.3120	0.2770	0.0350
year12	0.0201	0.0216	-0.0015
year13	-0.0523	-0.0564	0.0041
year14	0.0208	0.0130	0.0078
year15	0.0994	0.0851	0.0143
year16	0.1275	0.1080	0.0195
year17	0.1380	0.1207	0.0173
year18	0.2639	0.2449	0.0190
year19	0.2947	0.2722	0.0226

Auto-correlation: graphical approximation

Intra-EU exports / GDP: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

Dataset excludes Ireland

exp_r[country2,t] = Xb + u[country2] + e[country2,t]

Test:	Var(u) =	0
	chi2(1) =	401.57
	Prob > chi2 =	0.0000

Result: Within-unit correlation cannot be ruled out

Random effects model corrected for autocorrelation

Dependent variable: exp_r
Dataset excludes Ireland

xtregar exp_r tax fpr m_prod gpi3 year12-year19

Random-effects GLS regression			Number of obs =	117	
Group variable (i) : country2			Number of groups =	13	
R-sq:	within =	0.7871	Obs per group:	min =	9
	between =	0.2374		avg =	9
	overall =	0.2529		max =	9
			Wald chi2(24) =	163.16	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

exp_r	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.0700	0.2955	-0.2400	0.8130	-0.6491	0.5091
fpr	-0.3076	0.1634	-1.8800	0.0600	-0.6280	0.0127
m_prod	0.5311	0.1809	2.9400	0.0030	0.1766	0.8856
gpi3	0.2155	0.1019	2.1200	0.0340	0.0158	0.4151
year12	0.0348	0.0293	1.1900	0.2350	-0.0226	0.0921
year13	-0.0265	0.0395	-0.6700	0.5020	-0.1040	0.0509
year14	0.0727	0.0496	1.4600	0.1430	-0.0246	0.1699
year15	0.1644	0.0589	2.7900	0.0050	0.0489	0.2798
year16	0.1980	0.0657	3.0100	0.0030	0.0692	0.3268
year17	0.2315	0.0702	3.3000	0.0010	0.0940	0.3690
year18	0.3645	0.0741	4.9200	0.0000	0.2193	0.5097
year19	0.3859	0.0773	4.9900	0.0000	0.2345	0.5374
_cons	-6.1975	1.3189	-4.7000	0.0000	-8.7825	-3.6125
rho_ar	0.73317 (estimated autocorrelation coefficient)					
sigma_u	0.68642					
sigma_e	0.10974					
rho_fov	0.97508 (fraction of variance due to u_i)					
theta	0.84454					

Heteroskedasticity: graphical approximation

Intra-EU exports / GDP: Predicted values against residuals

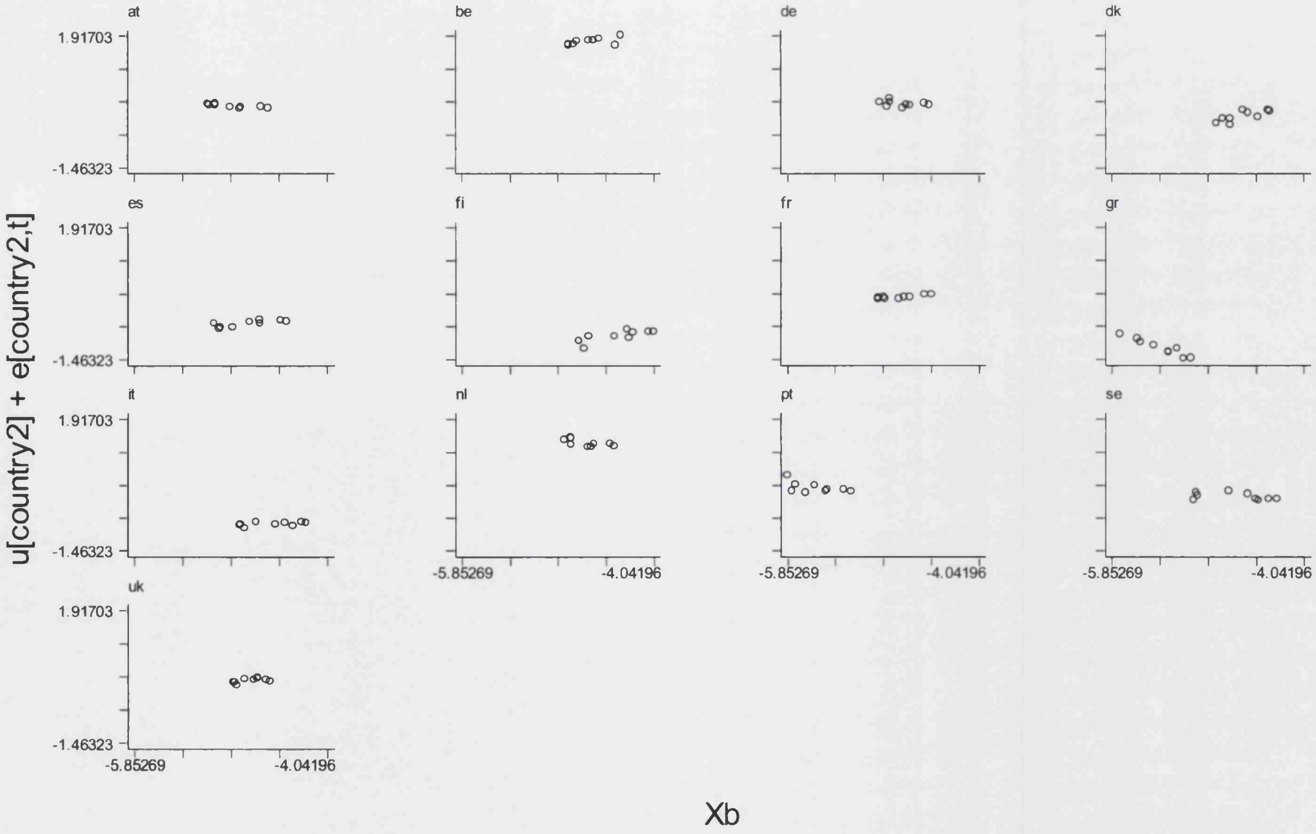


Table 52 Regression models on CI intra-EU export in absolute terms, Ireland included

Fixed effects model

Dependent variable: exp_a
Dataset includes Ireland

xtreg exp_a tax fpr m_prod gdp gpi3 year12-year19, fe

Fixed-effects (within) regression		Number of obs =	126	
Group variable (i) : country2		Number of groups =	14	
R-sq: within =	0.8618	Obs per group:	min =	9
between =	0.5749		avg =	9
overall =	0.5489		max =	9
		F(13,99) =		47.51
corr(u_i, Xb) =	0.4815	Prob > F =		0.0000

exp_a	Coef.	Std.	Err.	t	P>|t|	[95% Conf. Int.]
tax	-0.8553	0.3239	-2.6400	0.0100	-1.4979	-0.2126
fpr	0.1710	0.1545	1.1100	0.2710	-0.1356	0.4775
m_prod	0.2640	0.2581	1.0200	0.3090	-0.2482	0.7761
gdp	0.3876	0.1680	2.3100	0.0230	0.0543	0.7208
gpi3	0.1618	0.1059	1.5300	0.1300	-0.0484	0.3720
year12	0.0338	0.0431	0.7800	0.4340	-0.0517	0.1193
year13	0.0462	0.0486	0.9500	0.3430	-0.0501	0.1426
year14	0.0553	0.0525	1.0500	0.2940	-0.0488	0.1595
year15	0.2181	0.0650	3.3600	0.0010	0.0892	0.3470
year16	0.3392	0.0832	4.0800	0.0000	0.1741	0.5043
year17	0.3709	0.0879	4.2200	0.0000	0.1964	0.5453
year18	0.4881	0.0884	5.5200	0.0000	0.3127	0.6636
year19	0.5742	0.0957	6.0000	0.0000	0.3843	0.7642
_cons	2.7773	3.0607	0.9100	0.3660	-3.2957	8.8504
sigma_u	1.15048					
sigma_e	0.112519					
rho	0.990525 (fraction of variance due to u_i)					

F test that all u_i=0: F(13,99) = 421.21 Prob > F = 0.0000

Random effects model

Dependent variable: exp_a
Dataset includes Ireland

xtreg exp_a tax fpr m_prod gdp gpi3 year12-year19, re

Random-effects GLS regression		Number of obs =	126	
Group variable (i) : country2		Number of groups =	14	
R-sq: within =	0.859	Obs per group:	min =	9
between =	0.666		avg =	9
overall =	0.6627		max =	9
Random effects u_i ~ Gaussian		Wald chi2(24) =	621.86	
corr(u_i, X) = 0 (assumed)		Prob > chi2 =	0.0000	

exp_a	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.7852	0.3212	-2.4400	0.0140	-1.4146	-0.1557
fpr	0.1413	0.1533	0.9200	0.3570	-0.1592	0.4419
m_prod	0.5597	0.2307	2.4300	0.0150	0.1075	1.0119
gdp	0.5791	0.1389	4.1700	0.0000	0.3068	0.8514
gpi3	0.1668	0.1034	1.6100	0.1070	-0.0359	0.3695
year12	0.0353	0.0434	0.8100	0.4170	-0.0499	0.1204
year13	0.0171	0.0474	0.3600	0.7180	-0.0758	0.1100
year14	0.0361	0.0520	0.6900	0.4870	-0.0658	0.1381
year15	0.1673	0.0621	2.7000	0.0070	0.0457	0.2889
year16	0.2483	0.0754	3.3000	0.0010	0.1006	0.3960
year17	0.2801	0.0804	3.4800	0.0000	0.1224	0.4377
year18	0.4006	0.0816	4.9100	0.0000	0.2405	0.5606
year19	0.4705	0.0868	5.4200	0.0000	0.3005	0.6406
_cons	-0.7433	2.6406	-0.2800	0.7780	-5.9189	4.4322
sigma_u	0.973229					
sigma_e	0.112519					
rho	0.98681 (fraction of variance due to u_i)					

Hausman specification test

Test: Ho: difference in coefficients not systematic

chi2(24) = (b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
= 6.99

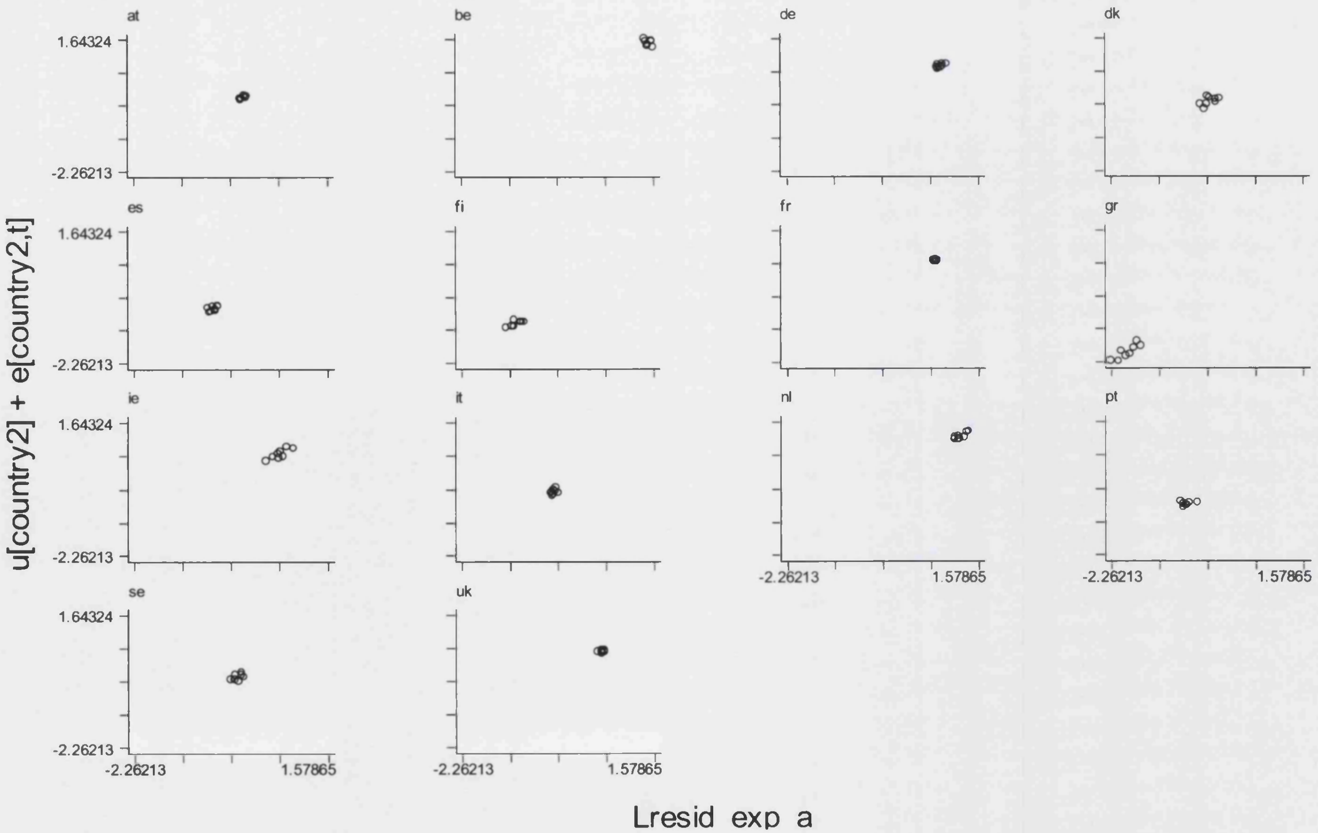
Prob>chi2 = 0.9026

Result: Ho cannot be rejected.
Random effects model can be used safely.

exp_a	FE	RE	Difference
tax	-0.8553	-0.7852	-0.0701
fpr	0.1710	0.1413	0.0296
m_prod	0.2640	0.5597	-0.2957
gdp	0.3876	0.5791	-0.1915
gpi3	0.1618	0.1668	-0.0050
year12	0.0338	0.0353	-0.0015
year13	0.0462	0.0171	0.0292
year14	0.0553	0.0361	0.0192
year15	0.2181	0.1673	0.0508
year16	0.3392	0.2483	0.0909
year17	0.3709	0.2801	0.0908
year18	0.4881	0.4006	0.0876
year19	0.5742	0.4705	0.1037

Auto-correlation: graphical approximation

Intra-EU exports in absolute terms: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

Dataset includes Ireland

exp_a[country2,t] = Xb + u[country2] + e[country2,t]

Test:	Var(u) =	0
	chi2(1) =	1714.78
	Prob > chi2 =	0.0000

Result: Within-unit correlation cannot be ruled out

Random effects model corrected for autocorrelation

Dependent variable: exp_a
Dataset includes Ireland

xtregar exp_a tax fpr m_prod gdp gpi3 year12-year19

Random-effects GLS regression			Number of obs =	126	
Group variable (i) : country2			Number of groups =	14	
R-sq:	within =	0.8512	Obs per group:	min =	9
	between =	0.6649		avg =	9
	overall =	0.6641		max =	9
			Wald chi2(25) =	275.35	
corr(u_i, X) = 0 (assumed)			Prob > chi2 =	0.0000	

exp_a	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	-0.2701	0.2748	-0.9800	0.3260	-0.8087	0.2685
fpr	-0.1403	0.1439	-0.9700	0.3300	-0.4223	0.1418
m_prod	0.4481	0.1794	2.5000	0.0130	0.0964	0.7998
gdp	0.6429	0.1284	5.0100	0.0000	0.3913	0.8945
gpi3	0.1124	0.1125	1.0000	0.3180	-0.1081	0.3329
year12	0.0438	0.0273	1.6100	0.1080	-0.0097	0.0973
year13	0.0214	0.0383	0.5600	0.5760	-0.0536	0.0965
year14	0.0711	0.0467	1.5200	0.1280	-0.0204	0.1626
year15	0.1993	0.0557	3.5800	0.0000	0.0901	0.3086
year16	0.2788	0.0659	4.2300	0.0000	0.1497	0.4079
year17	0.3260	0.0704	4.6300	0.0000	0.1880	0.4639
year18	0.4473	0.0719	6.2200	0.0000	0.3064	0.5882
year19	0.4889	0.0757	6.4600	0.0000	0.3406	0.6373
_cons	-0.8741	2.2476	-0.3900	0.6970	-5.2792	3.5310
rho_ar	0.75082 (estimated autocorrelation coefficient)					
sigma_u	0.74342					
sigma_e	0.10263					
rho_fov	0.98130 (fraction of variance due to u_i)					
theta	0.85851					

Heteroskedasticity: graphical approximation

Intra-EU exports in absolute terms: Predicted values against residuals

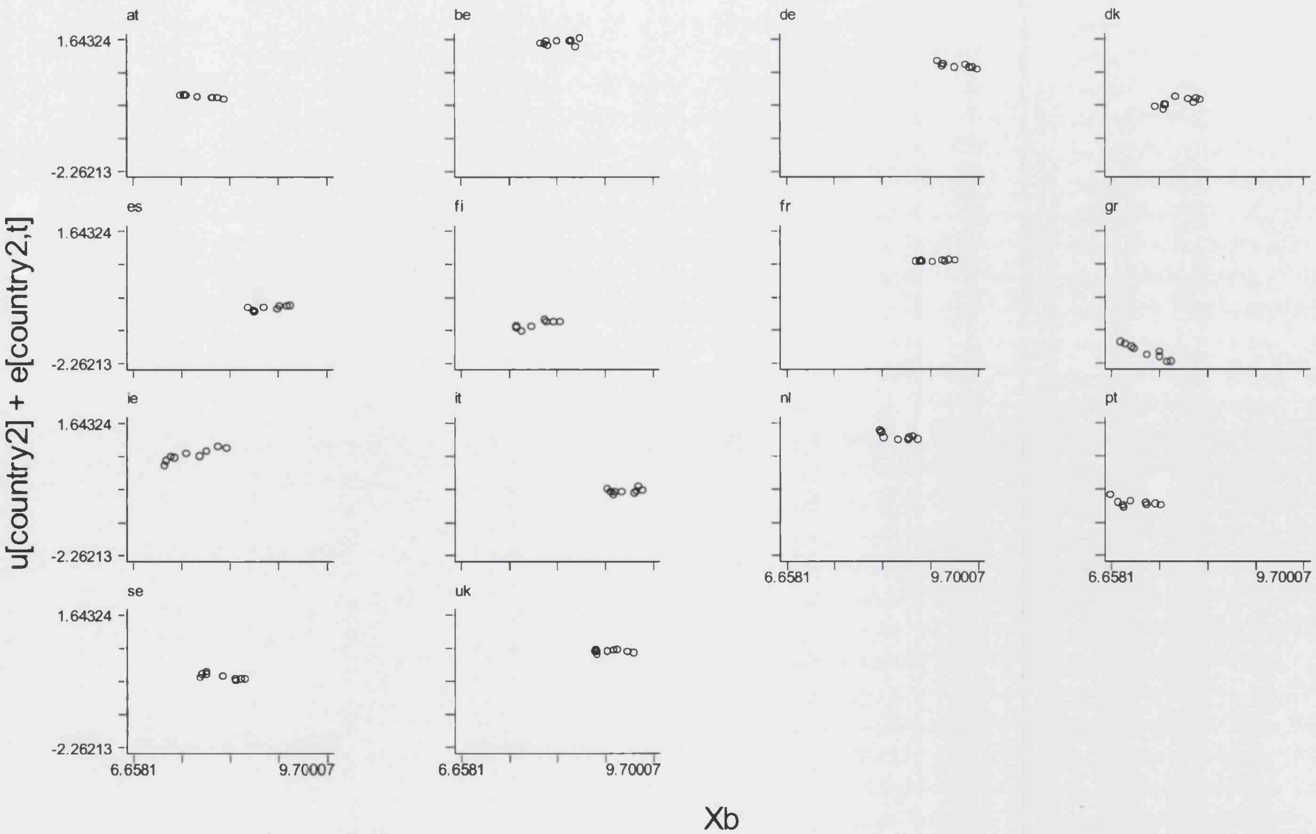


Table 53 Regression models on CI intra-EU export in absolute terms, Ireland excluded

Fixed effects model

Dependent variable: exp_a
Dataset excludes Ireland

xtreg exp_a tax fpr m_prod gdp gpi3 year12-year19, fe

Fixed-effects (within) regression		Number of obs =	117
Group variable (i) : country2		Number of groups =	13

R-sq:	within =	0.8919	Obs per group:	min =	9
	between =	0.3965		avg =	9
	overall =	0.1229		max =	9
			F(13,91) =		57.77
corr(u_i, Xb) =		-0.5225	Prob > F =		0.0000

exp_a	Coef.	Std.	Err.	t	P>|t|	[95% Conf. Int.]
tax	0.1137	0.2914	0.3900	0.6970	-0.4651	0.6926
fpr	0.0397	0.1324	0.3000	0.7650	-0.2234	0.3027
m_prod	0.2034	0.2095	0.9700	0.3340	-0.2129	0.6196
gdp	-0.2517	0.1599	-1.5700	0.1190	-0.5694	0.0660
gpi3	-0.0410	0.0890	-0.4600	0.6460	-0.2178	0.1358
year12	0.0286	0.0359	0.8000	0.4280	-0.0427	0.0999
year13	0.0655	0.0410	1.6000	0.1130	-0.0158	0.1469
year14	0.0062	0.0443	0.1400	0.8890	-0.0818	0.0942
year15	0.1906	0.0542	3.5200	0.0010	0.0831	0.2982
year16	0.4128	0.0697	5.9200	0.0000	0.2742	0.5513
year17	0.4309	0.0731	5.8900	0.0000	0.2856	0.5762
year18	0.4879	0.0727	6.7100	0.0000	0.3436	0.6323
year19	0.5594	0.0787	7.1100	0.0000	0.4031	0.7157
_cons	10.1631	2.6845	3.7900	0.0000	4.8307	15.4955
sigma_u	1.715486					
sigma_e	0.090107					
rho	0.997249 (fraction of variance due to u_i)					

F test that all u_i=0: F(12,91) = 522.79 Prob > F = 0.0000

Random effects model

Dependent variable: exp_a
Dataset excludes Ireland

xtreg exp_a tax fpr m_prod gdp gpi3 year12-year19, re

Random-effects GLS regression		Number of obs =	117
Group variable (i) : country2		Number of groups =	13

R-sq:	within =	0.8816	Obs per group:	min =	9
	between =	0.6646		avg =	9
	overall =	0.5828		max =	9
Random effects u_i ~ Gaussian			Wald chi2(13) =		621.9
corr(u_i, X) = 0 (assumed)			Prob > chi2 =		0.0000

exp_a	Coef.	Std.	Err.	z	P>|z|	[95% Conf. Int.]
tax	0.0084	0.3143	0.0300	0.9790	-0.6076	0.6244
fpr	0.0198	0.1444	0.1400	0.8910	-0.2632	0.3028
m_prod	0.5687	0.2078	2.7400	0.0060	0.1614	0.9761
gdp	0.1930	0.1437	1.3400	0.1790	-0.0887	0.4747
gpi3	0.0409	0.0937	0.4400	0.6620	-0.1428	0.2247
year12	0.0269	0.0395	0.6800	0.4970	-0.0506	0.1044
year13	0.0155	0.0436	0.3600	0.7220	-0.0699	0.1010
year14	-0.0055	0.0482	-0.1100	0.9100	-0.1000	0.0890
year15	0.1303	0.0571	2.2800	0.0230	0.0184	0.2422
year16	0.2742	0.0693	3.9600	0.0000	0.1385	0.4100
year17	0.2920	0.0733	3.9900	0.0000	0.1484	0.4356
year18	0.3705	0.0742	4.9900	0.0000	0.2250	0.5160
year19	0.4244	0.0794	5.3500	0.0000	0.2688	0.5799
_cons	3.2133	2.5025	1.2800	0.1990	-1.6915	8.1181
sigma_u	0.859034					
sigma_e	0.090107					
rho	0.989117 (fraction of variance due to u_i)					

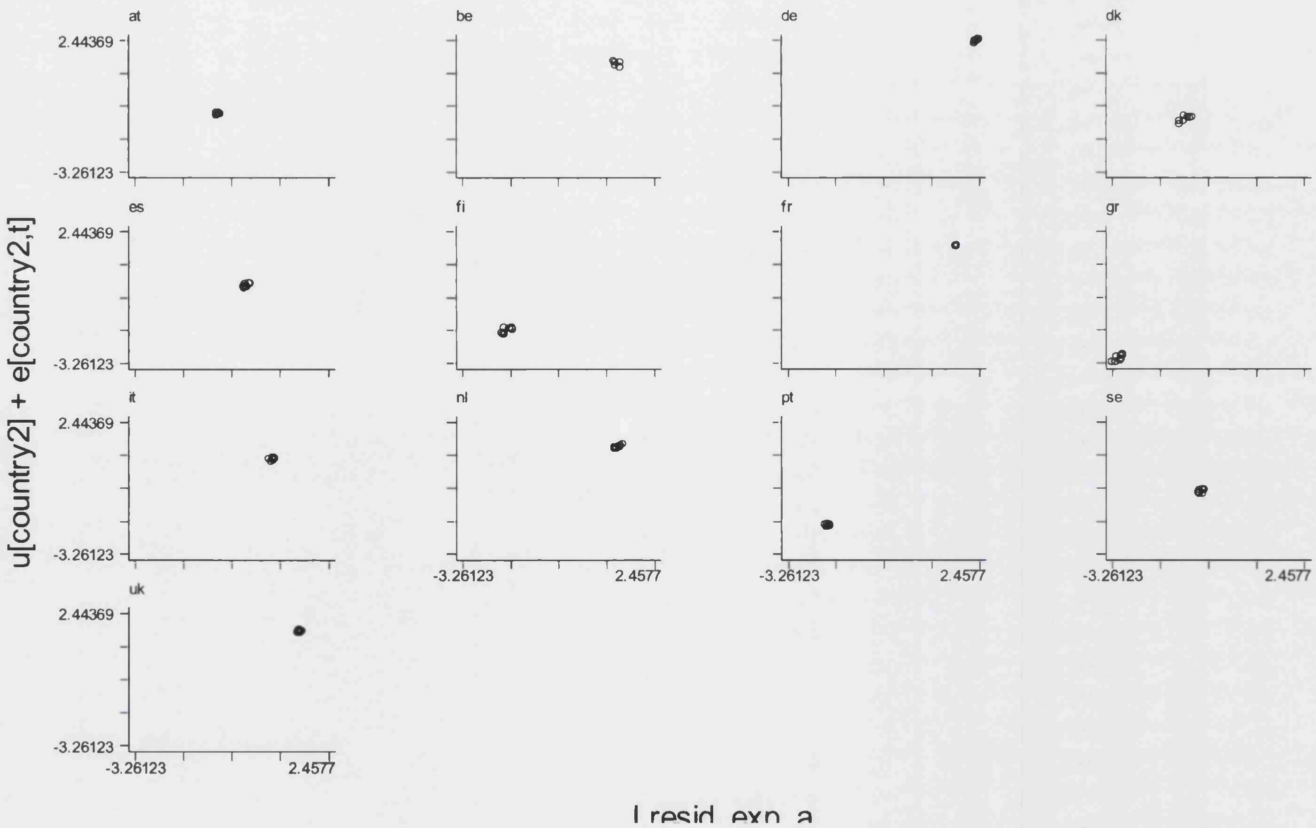
Hausman specification test

Test:	Ho: difference in coefficients not systematic
chi2(24) =	(b-B)'[S^(-1)](b-B), S = (S_fe - S_re)
=	40.24
Prob>chi2 =	0.0001
Result:	Ho rejected at 99 percent level.
	RE model <u>cannot</u> be used safely.

exp_a	FE	RE	Difference
tax	0.1137	0.0084	0.1053
fpr	0.0397	0.0198	0.0199
m_prod	0.2034	0.5687	-0.3654
gdp	-0.2517	0.1930	-0.4447
gpi3	-0.0410	0.0409	-0.0819
year12	0.0286	0.0269	0.0017
year13	0.0655	0.0155	0.0500
year14	0.0062	-0.0055	0.0117
year15	0.1906	0.1303	0.0603
year16	0.4128	0.2742	0.1385
year17	0.4309	0.2920	0.1389
year18	0.4879	0.3705	0.1174
year19	0.5594	0.4244	0.1350

Auto-correlation: graphical approximation

Intra-EU exports in absolute terms: Residuals against lagged residuals



Breusch and Pagan Lagrangian multiplier test

not possible, as this is a fixed effects regression model

Fixed effects model corrected for autocorrelation

Dependent variable: empl_a
Dataset excludes Ireland

xtregar exp_a tax fpr m_prod gdp gpi3 year12-year19, fe

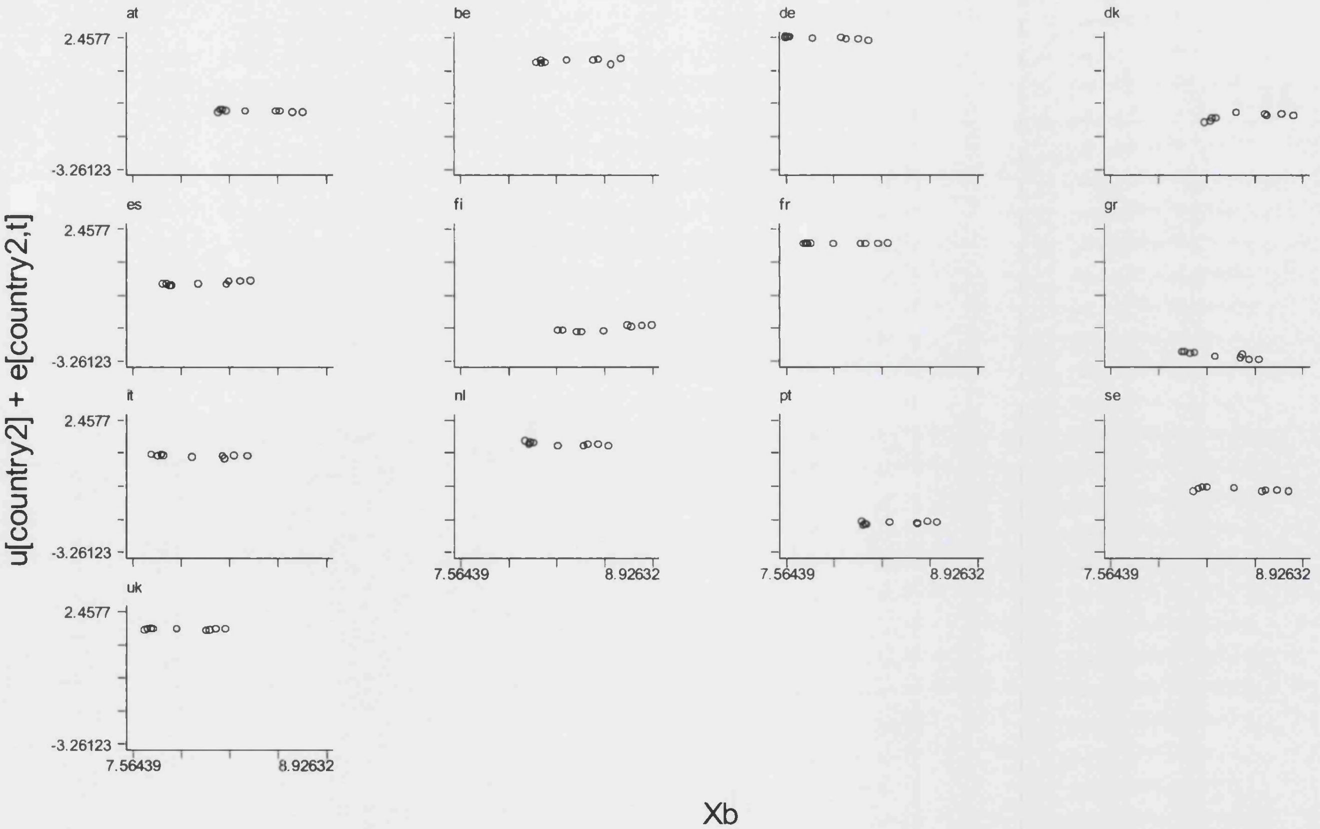
Fixed effects (within) regression			Number of obs =	104	
Group variable (i) : country2			Number of groups =	13	
R-sq:	within =	0.7621	Obs per group:	min =	8
	between =	0.6823		avg =	8
	overall =	0.6167		max =	8
			F (12,79)		21.09
corr(u_i, X) =		0.6745	Prob > chi2 =		0.0000

exp_a	Coef.	SE	z	P>|z|	[95% Conf.	Int.]
tax	0.2926	0.2334	1.2500	0.2140	-0.1720	0.7571
fpr	-0.2318	0.1517	-1.5300	0.1310	-0.5338	0.0702
m_prod	0.1113	0.1654	0.6700	0.5030	-0.2179	0.4405
gdp	0.1839	0.1981	0.9300	0.3560	-0.2105	0.5782
gpi3	-0.0627	0.1158	-0.5400	0.5900	-0.2931	0.1678
year12	-0.1607	0.0276	-5.8100	0.0000	-0.2157	-0.1057
year13	-0.2782	0.0309	-9.0000	0.0000	-0.3398	-0.2167
year14	-0.3473	0.0434	-8.0100	0.0000	-0.4336	-0.2610
year15	-0.2399	0.0357	-6.7200	0.0000	-0.3109	-0.1689
year16	-0.1115	0.0315	-3.5400	0.0010	-0.1741	-0.0488
year17	-0.1043	0.0302	-3.4600	0.0010	-0.1643	-0.0442
year18	-0.0339	0.0239	-1.4200	0.1600	-0.0815	0.0137
year19	(dropped)					
_cons	6.4716	1.0399	6.2200	0.0000	4.4017	8.5414
rho_ar	0.659922 (estimated autocorrelation coefficient)					
sigma_u	1.334821					
sigma_e	0.065957					
rho_fov	0.997564 (fraction of variance due to u_i)					

F test that all u_i=0: F(12, 79) = 107.33 Prob > F = 0.0000

Heteroskedasticity: graphical approximation

Intra-EU exports in absolute terms: Predicted values against residuals



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